REPORT ON RESEARCH,
INNOVATION AND TECHNOLOGICAL
PERFORMANCE IN GERMANY

COMMISSION OF EXPERTS
FOR RESEARCH
AND INNOVATION

EFI

REPORT

2022

2023 2024
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Foreword

The new Federal Government has begun its work in a difficult political and economic phase. The COVID-19 pandemic has dominated economic and social life for almost two years. Nevertheless, the many other important tasks that need to be tackled in the course of the grand societal challenges must not be left undone.

In the coalition agreement, the governing parties place a transformation of society and the economy towards greater sustainability at the centre of their programme for the new legislative period. High-quality research and innovation are indispensable prerequisites for the development and dissemination of new, more sustainable technologies. The COVID-19 crisis has shown how innovative solutions to medical and health problems can be found with the help of research – and, when it matters, very quickly. This experience of what is possible under pressure can be very helpful when it comes to shaping transformative change in the coming years.

The coalition agreement identifies the key problems of research and innovation policy, formulates ambitious goals, and backs them up, at least in part, with concrete measures. The governing parties obviously have great ambitions, not least to use research and innovation to secure the position of the German economy in the face of increasingly fierce international competition and thus to create the conditions for the successful and socially acceptable overcoming of the grand societal challenges ahead.

To master this, the Federal Government must provide sufficient and reliable financial resources for the promotion of research and innovation. However, it must also reform existing structures and processes in such a way that these funds have the desired effects and advance economic and social transformation. To this end, established patterns of thought and previous research and innovation policy actions must be put to the test. At the same time, it is important to develop concepts for agility in politics as well as modern management and administrative structures to match, with the aim of putting new ideas and approaches into practice more quickly and efficiently – even on a trial basis and with the risk of failure.

Planned and intelligent action to tackle the grand societal challenges ahead requires the rapid conception of a comprehensive strategy for a research and innovation policy that extends beyond the legislature and is transformation- and mission-oriented. This must also take into account the social acceptance and social side effects of transformative change.

Radical new technologies are paving the way for a successful transformation towards more sustainability. Yet these cannot develop their intended effects, or at least not to their full extent, if citizens do not accept them. Therefore, complementary social innovations and attitudinal changes are necessary. This has become evident in the COVID-19 crisis, for example. Although vaccines were quickly developed, due to a lack of willingness to be vaccinated, the pandemic was not contained as much as would have been possible if vaccination had been more widely accepted. Consequently, a goal-oriented research and innovation policy strategy must consider social preconditions as well as structures and incentive systems that support social innovations and changes in attitudes across the entire spectrum of society from the outset.

Successful transformative processes and radical technological change produce new business models that create additional value and employment opportunities. At the same time, however, established business models are being called into question or are becoming obsolete altogether. Not all economic stakeholders can easily cope with the structural adjustments this requires. It is therefore necessary that a research and innovation policy strategy also clearly addresses the anticipated negative social side effects as well as the preventive, protective and compensatory measures suitable for mitigating them.

Against this background, the Commission of Experts has developed recommendations for action in research and innovation policy for the new Federal Government in the report at hand. With its proposals, it seeks to provide fundamental orientation and point out new paths and options for research and innovation policy. In doing so, the Commission of Experts takes into account the existing structures of the German R&I system and considers the difficulties of political and social consensus-building.

In the A chapters, the Commission of Experts addresses R&I policy in the new legislative period. In chapter A 0, it advocates developing a new, comprehensive research and innovation strategy based on the experiences of the High-Tech Strategy and making the necessary investments for the future. In chapter A 1, the Commission of Experts discusses how to create stronger incentives for the development and diffusion of low-carbon technologies. It attaches particular importance to CO_2 pricing. Based on the observation that Germany is lagging behind in key digital technologies, the Commission of Experts emphasises in chapter A 2 the need to further promote research and innovation activities in this area, to drive forward the expansion of the digital infrastructure and to exploit the innovation and value creation potential of data. Chapter A 3 deals with strengthening the skilled labour supply through education and qualification. The Commission of Experts emphatically points out that to ensure a good supply of suitably qualified workers, schools and universities as well as vocational and continuing education and training must become more efficient, more needs-based and more socially permeable. Chapter A 4 discusses how the existing downward trend in the innovator rate can be counteracted. In this context, the Commission of Experts advocates improving the conditions for start-ups and focusing research and innovation funding on potential. In chapter A 5, the Commission of Experts proposes adapting existing governance structures, promoting agile policy action and integrating policy learning more firmly into existing processes.

Key enabling technologies unlock high potentials for a prosperous technological and economic development of a national economy. They are of vital importance for current and future value creation activities. In chapter B 1, the Commission of Experts concludes that Germany has strengths in the key enabling technology areas of production technologies as well as bio- and life sciences. In the area of digital technologies, however, Germany and the EU 27 show clear weaknesses. This means that they are not only losing touch in a technology area that is becoming increasingly important economically but are also jeopardizing their existing strengths in production technologies as well as in the bio- and life sciences, which are increasingly being penetrated by digital technologies.

According to the Climate Protection Act, Germany must become climate neutral by 2045. In chapter B 2, the Commission of Experts analyses the role of private motorized transport in reducing greenhouse gas emissions. At the vehicle level, a reduction of these emissions can be achieved using new drive systems and alternative fuels. The Commission of Experts therefore recommends reducing the attractiveness of conventional internal combustion vehicles by means of a sufficiently high CO_2 price. In addition, the system of taxes and charges for passenger cars should be reformed and directly aligned with the use of passenger cars. As developments in autonomous driving create opportunities for bundling transport, the legal framework for passenger transport should not hinder the development of these innovative mobility services.

In chapter B 3, the Commission of Experts analyzes the effects that the use of digital B2B platforms can have on companies' innovation activities and the challenges that companies face when using them. Companies see many advantages of B2B platform use for their own innovation activities, for example through simplified access to data and the integration of external partners in the innovation process. At the same time, they have concerns about data protection and IT security and fear the outflow of knowledge relevant to innovation and competition. To leverage the potential associated with digital B2B platforms, the Commission of Experts recommends improving the conditions for data-based B2B business models and pushing for uniform platform regulation across the EU.

In chapter B 4, the Commission of Experts addresses the digitalization of the healthcare system, which is associated with great potential for innovation and value creation with regard to better quality and more efficient healthcare. In particular, the increasing availability of health data in combination with new digital analysis methods creates opportunities for more personalized diagnostics and treatment. In international comparison, Germany lags far behind other European countries in the digitalization of the healthcare system. To remove existing obstacles and to be able to leverage the innovation potential associated with digitalization, a digitalization strategy is needed, as well as a coordinating body with the broadest possible enforcement powers for its implementation.

Berlin, 23 February 2022

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EXECUTIVE SUMMARY

Executive Summary

A Current developments and challenges

A 0 R&I Policy in the New Legislative Period

The governing parties have outlined their plans for the new legislative period in the coalition agreement. They have expressed the will to tackle the major social challenges with vigour and to set the course for a social-ecological market economy. The transformative change required for this can only be realized with considerable, often radical technological innovations, social innovations, and complementary behavioural changes. The Commission of Experts advocates building on the experiences of the High-Tech Strategy to develop a new, comprehensive R&I strategy and to add a qualitative dimension to the 3.5 percent target. Furthermore, a future quota should be introduced for the federal budget.

A 1 Tackling Climate Targets Vigorously

In order for Germany to achieve its ambitious climate goals, the development of low-CO_2 technologies must be further advanced and their diffusion into the markets promoted. In addition to the instruments of R&I policy, CO_2 pricing is of particular importance here. According to the Commission of Experts, the incentive effects of European and national emissions trading must be increased. Furthermore, the price components in the energy sector associated with state intervention should be reformed quickly and climate-damaging subsidies dismantled. By establishing an international climate club with a common CO_2 border adjustment mechanism, competitive disadvantages of low-emission technologies in the participating countries should be compensated for compared to cheaper emission-intensive technologies from outside.

A 2 Catching Up and Avoiding Technological Gaps

Germany shows considerable weaknesses in the development of digital technologies. There is a danger of not keeping pace in this central key enabling technology. The Commission of Experts is in favour of further promoting key digital technologies on the basis of strategies and framework programmes and of making greater use of the innovation and value creation potential of data than has been the case to date. In addition, the Commission of Experts considers it necessary to further accelerate the expansion of the digital infrastructure and to strengthen cybersecurity in light of an intensified threat situation. Furthermore, Germany should vigorously promote e-government.

A 3 Strengthening the Skilled Labour Base Through Education and Training

In order for Germany to realize the innovations and productivity gains required to cope with the ongoing transformations and major tasks of the future, the strengthening of the skilled labour base should be accelerated. To improve STEM skills, the Commission of Experts recommends that learning content and teaching methods in schools be put to the test, that impending bottlenecks in the supply of qualified teachers in STEM subjects be combated more actively and that the school subject of computer science be expanded. It advises making in-company vocational training more attractive from both the supply and demand sides and thus stabilising it. Likewise, vocational adaptability should be boosted through further training, especially through preventive bridging solutions.

A 4 Increasing Innovation Participation

To counteract the declining trend in Germany's innovator rate, the conditions for participation in R&I activities should be improved with the help of tailored support measures. This could be done, for example, through a comprehensive start-up strategy. The Commission of Experts considers it necessary to considerably professionalize the start-up and transfer infrastructure at universities. Access to venture capital should be improved by further developing the Future Fund – by creating funding modules for socially and ecologically oriented projects as well as specifically for female founders. The Commission of Experts is against mixing R&I policy and structural policy goals. Against the backdrop of differing regional conditions, it proposes that R&I funding be oriented towards potential.

A 5 Developing Agile Governance Structures

The R&I policy tasks associated with the upcoming transformative change require agile policy action. To this end, suitable governance structures must be developed and policy learning must be more strongly integrated into political processes. The digital policies of the various ministries are to be coordinated and harmonized more closely than before following the new allocation of competences. To this end, interfaces must be clearly defined and structurally anchored through interdepartmental project teams or task forces. The Commission of Experts is against relying on agency solutions as a panacea in R&I policy. It considers evaluations of R&I policy measures that are carried out systematically and with suitable methods to be important in order to learn from them for the design of future funding measures.

B Core Topics 2022

B 1 Key Enabling Technologies and Technological Sovereignty

Unique selling propositions and innovations in key enabling technologies contribute to the competitiveness of an economy's companies in these technologies.

In an international comparison, Germany shows strengths in the key enabling technology areas of production technologies as well as bio- and life sciences. In the area of digital technologies, on the other hand, Germany, like the EU 27, shows clear weaknesses and is also heavily dependent on imports from China.

The Commission of Experts therefore makes the following recommendations:

— Key enabling technologies and derived key enabling technology portfolios must be defined using clear and operationalizable criteria to ensure that their selection is not determined by assertive individual interests.

— Key enabling technologies should be systematically kept under review through continuous foresight analyses and monitoring processes. The aim of these processes must be to record current, emerging and potential key enabling technologies and to evaluate them in terms of their technological, economic and societal potential.

— The Federal Government should establish an independent strategic advisory body for key enabling technologies with the task of continuously updating a key enabling technology portfolio and developing recommendations for action for the Federal Government on how to deal with selected key enabling technologies.

— In key enabling technology areas where technological leaps are emerging, application-oriented pilot projects should be supported in addition to basic research. The development of competences for key enabling technologies must be initiated at an early stage in academic education as well as in vocational and continuing education and training.

— The Federal Government should not only focus its funding on the pre-market phase. To promote potential key enabling technologies (infant technologies), the Commission of Experts also recommends targeted market interventions, provided they have a catalytic character.

— To reinforce key enabling technologies and their own technological sovereignty, Germany and the EU should take stronger joint action to achieve a critical mass of capacities and activities.

B 2 Motorized Private Transport on the Road to Sustainability

German policy is faced with the major challenge of having to bring emissions from the transport sector to zero as early as 2045. Private motorized transport is a major source of greenhouse gas emissions. At the vehicle level, a reduction of these emissions can be achieved using new drive systems and alternative fuels. The battery-powered passenger car is proving to be the most ecologically and economically advantageous alternative. Furthermore, developments in digitalization and autonomous driving create opportunities for innovative mobility services such as car sharing and on-demand transport, which can contribute to reducing emissions through shared vehicle use or the bundling of transport.

The Commission of Experts therefore recommends:

— Appropriate measures should be taken to quickly realize a sufficiently high CO_2 price to reduce the attractiveness of conventional combustion engines and at the same time give companies planning security regarding the marketability of e-mobility and future development of alternative drive systems.

— The system of taxes and charges should be fundamentally reformed by reducing flat-rate taxes, such as vehicle tax, and instead levying more usage-based charges, such as tolls and parking fees.

— The supply of CO_2-neutral electricity should be increased through the expansion of renewable electricity sources.

— Electricity should be exempted from additional financial burdens without a steering effect, such as the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) levy and the electricity tax, to keep electricity prices low.

— The development of new types of batteries with a lower ecological footprint should be vigorously promoted.

— The current purchase premium system for the purchase of electric cars should be phased out by 2025 as planned.

— Plug-in hybrids should be immediately excluded from purchase premiums, as they perform significantly worse in the environmental balances than battery electric vehicles.

— Pricing of CO_2 and other externalities should be achieved through a combination of a CO_2 price and a correspondingly adjusted petrol/diesel tax.

— Section 50 of the Passenger Transport Act (Personenbeförderungsgesetz, PBefG) should be reformed so that municipalities can exert less influence on the providers of bundled on-demand transport.

B 3 Innovations in the Platform Economy

Digital platforms orchestrate the interaction of different stakeholder groups and enable the development of innovative business models and new products and services. Companies that use digital B2B platforms see many advantages for their own innovation activities, for example, through simplified access to data and the integration of external partners in the innovation process. The potential for value creation by means of B2B platforms and especially using data-based platforms in the industrial sector is estimated to be high for the German economy.

It is important to leverage this potential and avoid a drain of value creation to the large B2C platforms from the USA and China that are increasingly penetrating the B2B sector. The Commission of Experts therefore recommends:

— The requirements of the Open Data Directive and measures of the Open Data Strategy should be implemented quickly and consistently.

— The Federal Government is requested to review the progress of GAIA-X in a timely manner and at regular intervals. If it becomes apparent that GAIA-X is falling significantly and permanently short of the targets set, funding should be adjusted accordingly.

— The framework conditions for data intermediaries in the planned Data Governance Act should be designed in such a way that stakeholders have an incentive to offer such intermediary services and high-quality services are ensured.

— To increase trust in B2B platform ecosystems, the creation of B2B platforms that companies operate and design collaboratively should be encouraged.

— Data literacy training should be further reinforced. Against this background, the Commission of Experts welcomes the extension of the go-digital support programme until the end of 2024 and in particular the newly included go-data module.

— Based on the welcome regulations in the German Act Against Restraints of Competition Digitalization Act (GWB-Digitalisierungsgesetz) and in the planned Digital Markets Act (DMA) for the improvement of data portability and interoperability of digital platforms, suitable criteria must be developed in order to be able to check the implementation of these regulations.

— The Federal Government and the European Commission should advocate for EU-wide uniform platform regulation.

— It is necessary to evaluate the regulatory measures such as the tenth GWB amendment or the DMA for their innovation effects after their introduction. The emergence of similarly high market concentrations as in the B2C sector should be prevented.

B 4 Digital Transformation in the Healthcare System

The digitalization of the healthcare system is associated with great potential for innovation and value creation regarding better quality and more efficient healthcare. In particular, the increasing availability of health data in combination with new digital analysis methods creates opportunities for more personalized diagnostics and treatment. In international comparison, Germany lags far behind in the digitalization of the healthcare system.

The Commission of Experts recommends the following measures to reduce existing barriers and to be able to leverage the innovation potential associated with digitalization:

— The digitalization strategy for the healthcare system announced in the coalition agreement should be developed and implemented quickly. All relevant stakeholders should be involved in the development. A coordinating body with the broadest possible enforcement powers should be created or commissioned for implementation.

— To enable an efficient and frictionless exchange of data and information and to ensure interoperability between IT systems, sufficient space must be given to the establishment of interoperable and international standards as part of the digitalization strategy for the healthcare system.

— The GDPR-compliant scientific use of health data, to which from the point of view of the Commission of Experts the Health Data Use Act (Gesundheitsdatennutzungsgesetz) announced in the coalition agreement can make a contribution, should be designed for researchers in such a way that the administrative burden is as low as possible.

— It is welcome that a GDPR-compliant electronic patient record (ePR) is to be made available to all insured persons via opt-out. To be able to leverage the potential associated with ePR data, the possibility of releasing the data, especially for research purposes, should be designed to be as low-threshold as possible.

— For the possibilities of telemedicine to be used more, sufficient financial incentives are required for the service providers. Where this is not the case at present, equal services should therefore be remunerated equally in the introductory phase.

— Digital health applications (DiGA) providers must present various proofs of medical evidence, among other things, as part of the approval process. Although this is a mandatory requirement for ensuring quality healthcare, the introduction of flexible, adaptive study designs and requirements should be explored. After approval, the functionality and effectiveness of the digital health applications should be continuously monitored.

— To provide incentives for quality improvement on the part of the digital health applications providers and to guarantee the quality of the digital health applications, suitable performance-based remuneration models should be introduced.

A

CURRENT DEVELOPMENTS AND CHALLENGES

A 0 R&I Policy in the New Legislative Period

The governing parties have outlined their plans for the new legislative period in the coalition agreement 'Mehr Fortschritt wagen – Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit' (Dare More Progress – Alliance for Freedom, Justice and Sustainability).[1] They have expressed the will to tackle the grand societal challenges with vigour and to set the course for a social-ecological market economy. The new federal government will have to be judged by the extent to which it succeeds in driving transformative change in the economy and society and shaping it in a socially acceptable way. These complex tasks can only be mastered if they are tackled with clever concepts and verve.

Radical Innovation Needed for Transformative Change

The Federal Government cannot rely on the fact that it is sufficient to continue to develop the technologies and economic sectors that have made Germany economically strong in recent decades, and to focus on incremental innovations geared to the highest quality and greatest efficiency. This transformative change can only be realized with considerable, often radical technological innovations, social innovations and complementary behavioural changes. Previously used technologies and existing business models will be replaced and existing consumption patterns will be questioned. At the same time, new potential for value creation will emerge, which must be exploited.

For transformative change to succeed, a change of mindset and a willingness to take entirely new paths are required – not only from business and society, but also from politics. Research and innovation policy (R&I policy) can and must make important contributions here, especially in interaction with other policy areas. In addition to the task of pushing the development and use of radically innovative technologies and supporting social innovations, R&I policy itself must also be renewed – through new formats and structures of funding policy as well as through a cultural change towards more agility.

In its Annual Report 2021, the Commission of Experts has already formulated which new paths must be taken and which new research funding structures must be set up.[2]

Developing a Comprehensive Research and Innovation Strategy

The Commission of Experts considers it necessary to develop a new, comprehensive R&I strategy based on the experiences of the High-Tech Strategy (HTS). The results of the research accompanying the HTS should be taken into account for conceptual and content-related improvements.[3]

As R&I policy is increasingly called upon to contribute to addressing the grand societal challenges, the policy approach of New Mission Orientation should be increasingly pursued and further developed in the new R&I strategy. This policy approach is characterized by so-called missions that contain specific transformation objectives and are to be pursued through R&I policy and complementary measures of other policy fields. The Commission of Experts dedicated a separate chapter to New Mission Orientation in its Annual Report 2021 and refers to the recommendations for action formulated there.[4]

The governing parties have announced that they will continue to develop the HTS in a mission-oriented manner. The coalition agreement does not contain any further references to the new R&I strategy. The Commission of Experts emphasizes that it is necessary to develop a holistic R&I strategy that encompasses the entire innovation process. The new Federal Government needs a coherent policy approach that incorporates R&I processes in their diversity and totality with all facets and to which all ministries feel committed. The German innovation system must be equipped to successfully produce not only incremental, but also radical innovations. Technological and social innovations as well as new business models should be given equal consideration in the new R&I strategy. Research and development activities (R&D activities) are to be considered from basic research to applied research and experimental development. At the same time, however, innovation processes that are not based on R&D must also be initiated.[5] In addition, there must be a greater focus on transfer to economic and social application.

Expanding 3.5 Percent Target to Include Qualitative Dimensions

In its task of implementing a comprehensive R&I strategy, the Federal Government can rely on strong stakeholders in science, business, society and politics. In the past two decades, the German R&I system has developed very well – a joint success of private-sector R&I activities and a broad state funding policy. This success is reflected in the national R&D intensity, which is an important measure for assessing the performance of national innovation systems. After reaching the three percent target in 2017, Germany has now caught up with the international top group and is aiming for the 3.5 percent target (see figure C 2-1). Germany has thus certainly lived up to its claim to play a leading international role as a location for innovation.

The Commission of Experts welcomes the fact that the governing parties are pursuing the 3.5 percent target.[6] In transformative change, however, it is not only the level of R&D expenditure that matters, but also the areas in which R&D is being conducted. Yet the available statistics only allow limited statements to be made about the use of R&D expenditure for current R&I policy priorities. The Commission of Experts therefore sees the need to expand the purely quantitative parameter of 'R&D expenditure' to include qualitative dimensions. This cannot be reflected in the corresponding statistics for R&D processes in companies and universities. However, according to the Commission of Experts, federal expenditure on R&D can be appropriately classified. To this end, the Federal Government's R&D planning system (Leistungsplansystematik), which was last revised in 2009, must be further developed so that individual funding items can be assigned to different current policy goals. This can contribute to improved monitoring processes and thus to better R&I policies.

Box A 0-1 R&I Activities in the COVID-19 Crisis

R&D Intensity

Business sector, public sector and tertiary education institutions spent just under €106 billion on R&D in 2020. In the previous year, it was still €110 billion.[7] This means that the R&D intensity, i.e. the share of the gross domestic product that is allocated to R&D, fell from 3.17 percent in 2019 to 3.14 percent in 2020, despite the lower gross domestic product.

Innovation Behaviour in the Business Sector

As part of the Mannheim Innovation Panel (Mannheimer Innovationspanel, MIP), companies were surveyed in the course of 2021 about their innovation expenditures made in 2020 as well as their planned innovation expenditures in 2021 and 2022.[8]

In 2020, innovation expenditure by companies in Germany fell by 3.6 percent compared to 2019, to €170.5 billion. At the time of the survey (spring and summer 2021), companies planned to increase their innovation expenditure by 2.1 percent and 1.2 percent respectively in 2021 and 2022 compared to the previous year.[9] Provided that innovation expenditure in 2021 and 2022 was or will be implemented as planned, it will remain just below the 2019 level in 2022.

Investing in the Future Despite the COVID-19 Crisis

The conditions for advancing transformative change have deteriorated because of the pandemic. To date, there has only been a slight decline in current and planned R&I activities (see box A 0-1). However, the immense new debt of the Federal Government poses a severe problem.[10] The debt brake enshrined in the German constitution will also restrict the political room for manoeuvre in R&I policy in the coming years. It is therefore more important than ever to set priorities wisely.

In the coalition agreement, the governing parties declared that they would ensure the necessary investments in the future, especially in climate protection, digitalization, education and research as well as infrastructure, within the framework of the debt brake.[11] The Commission of Experts is in favour of transparently communicating the time frame of all Federal Government expenditures planned for this purpose and introducing a future quota for the federal budget. The ZEW – Leibniz Centre for European Economic Research GmbH Mannheim (ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung GmbH) has developed a practicable concept for such a future quota on behalf of the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF). In addition to traditional investments, the calculation also considers expenditures for maintaining and increasing human capital, natural capital and technical knowledge.[12]

A 1 Tackling Climate Targets Vigorously

Germany has set itself ambitious goals in the fight against climate change, which the new Federal Government intends to pursue even more vigorously. To this end, the development of low-carbon (low-CO_2) technologies must be initiated and further advanced – from new energy carriers such as hydrogen and alternative fuels, to new storage media and short-term electricity storage, digital control and smart grids. In addition, measures must be taken to promote the diffusion of these technologies into the markets, as they still have price disadvantages compared to established climate-damaging technologies. To promote innovations related to sustainability and climate change, suitable investment and purchasing incentives must be created for companies and consumers. In addition to the classic instruments of R&I policy, CO_2 pricing and thus the damage-adequate charging of established climate-polluting technologies are of particular importance in this context. This makes new climate-neutral technologies more attractive and competitive, enabling them to spread more quickly on the markets. Because the price increases for goods and services due to the CO_2 price hits low-income households particularly hard, appropriate measures must be taken to socially compensate for the effects of the CO_2 price via the tax and transfer system.

Increasing the Incentivising Effects of Emissions Trading

Through the European Union Emissions Trading System (EU ETS), a CO_2 price is formed on the market for the CO_2 emissions of the energy sector and the emissions-intensive industrial sectors. For a long time, however, this market price was too low to provide significant incentives to develop and demand climate-neutral technologies and products. Although the price has recently increased noticeably,[13] the Commission of Experts welcomes the plans of the governing parties to advocate an ETS minimum price at the European level[14] to create reliable incentives for the development and diffusion of innovative low-carbon or even CO_2-neutral technologies.[15]

As part of the Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz, BEHG) passed in 2019, CO_2 pricing now is regulated for the transport and heat sectors, which had not been previously included in the EU ETS. [16] In 2021, tradable emission certificates were introduced for these two sectors, which are to be sold at a fixed price until 2025 and auctioned from 2026. A price corridor of at least €55 and a maximum of €65 has been set for the year 2026. However, the Commission of Experts does not consider the fixed prices or the price cap to be sufficiently high to initiate an innovation and diffusion process that would enable the goal of net greenhouse gas neutrality by 2045 as set out in the Federal Climate Protection Act (Bundesklimaschutzgesetz). The Commission of Experts therefore welcomes the government parties' plan to reform the BEHG, as outlined in the coalition agreement,[17] and recommends that the system be transformed as quickly as possible into a genuine emissions trading system that at most allows for a minimum price. It also supports the intention to transfer national emissions trading to the European Emissions Trading Scheme ETS 2 planned by the European Commission.[18] The Commission of Experts considers the differentiation of reduction targets by sector provided for in the Federal Climate Protection Act to be impracticable and sees the problem that this does not result in the most cost-effective investments being made to save CO_2.

Critically Examining the Climate Impact of Subsidies

The Immediate Climate Protection Programme 2022 (Klimaschutz Sofortprogramm 2022) indicated that the initial financial support for the switch to climate-friendly technologies is to be gradually replaced by price incentives and regulatory measures.[19] The coalition agreement now provides for super depreciation for climate protection investments.[20] Although this instrument can generate significant innovation effects in the area of climate-friendly technologies and business models, it is in essence a new subsidy. The Commission of Experts points out that depreciation rules for special climate-friendly investments are always associated with the risk of greenwashing in the application process. Moreover, the demarcation between climate-protecting and non-climate-protecting investments is always subject to a certain arbitrariness.[21] The Commission of Experts therefore recommends that the instrument of super depreciation as a catalyst be limited in time. In the long term, efficient innovation incentives should be set in all sectors via a sufficiently high CO_2 price.

The governing parties have also agreed to fundamentally reform the state-induced price components in the energy sector, i. e. levies, surcharges and taxes on energy, and to reduce subsidies that are harmful to the environment and climate.[22] The Commission of Experts supports this plan and calls for swift implementation. However, since the examination of the harmfulness of subsidies to the climate can be complex in individual cases and the result may not always be clear,[23] the Commission of Experts advocates a general reduction in the level of subsidies.

Testing New Incentive Instruments with Carbon Contracts for Difference

In its pilot programme Carbon Contracts for Difference (CCfD)[24], the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, BMUV; in the previous legislative period Federal Ministry for the Environment, Nature Conservation and Nuclear Safety – Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, BMU)[25] plans to test an instrument to promote fundamentally mature technologies whose market introduction is not worthwhile at the prevailing CO_2 price level.[26] Through CCfD[27], differences between CO_2 avoidance costs and the respective current market price for emission certificates are compensated up to an agreed amount. This can provide additional incentives for investment and innovation.[28]

The Commission of Experts is ambivalent about this instrument. On the one hand, it welcomes in principle the testing of new incentive mechanisms such as CCfD within real-world laboratories. In particular, it supports the intended use of bidding procedures to promote the most efficient companies and technologies. At the same time, the Commission of Experts points out that CCfD is also a new form of subsidy that entails a number of problems. On the one hand, it is fundamentally subject to state aid law.[29] On the other hand, the instrument can lead to competitive sustainable technologies being held back by companies in order to then offer them via CCfD. In addition, it needs to be clarified how the baseline emission levels are to be determined, the undercutting of which then counts as an emission reduction in the sense of the CCfD. Moreover, the draft policy provides for the promotion of certain technologies and is thus not designed to be open to new technologies. Finally, the draft contains several complex rules and conditions whose practicability is questionable. The Commission of Experts therefore recommends testing and evaluating the instrument within a limited time and technology range. In principle, the Commission of Experts considers the introduction of minimum CO_2 prices to be the much more practicable, less distorting and easier to implement instrument.

Developing Long-term Strategies for Negative Emissions

To limit the expected overshooting of the 1.5 degree target,[30] net-negative CO_2 emission paths must be established. Therefore, in addition to incentives to avoid emissions, it is necessary to implement measures to remove CO_2 from the atmosphere and store it safely in geological formations or in the deep sea, so-called negative emissions. The Commission of Experts welcomes the plans of the government parties to develop a long-term strategy on negative emissions.[31] There is still a considerable need for R&D in various terrestrial and marine approaches to increase natural atmospheric CO_2 removal as well as in approaches to technical CO_2 removal, so-called direct air capture, with regard to implementation and scaling. This need should be met through public funding. In the future, to promote the diffusion of negative emission technologies, negative emissions and CO_2 reductions should be treated equally in the EU ETS, provided that verification is reliable.[32]

Establishing Climate Clubs

Domestic low-emission technologies are in international competition with lower-cost emission-intensive technologies. Although a CO_2 price provides investment and innovation incentives for low-emission technologies at home, it also carries the risk that emission-intensive production processes will shift abroad and correspondingly emission-intensive products will be imported from abroad. The establishment of an international climate club with a uniform minimum CO_2 price ensures a level playing field within the club. With a common CO_2 border adjustment mechanism, low-emission technologies within the club are protected from competition with cheaper emission-intensive technologies from outside.[33] To compensate for international differences in CO_2 pricing, a levy based on the CO_2 footprint of imports is imposed on imported goods. These measures can create incentives for the development of low-emission technologies both inside and outside the climate club. The Commission of Experts therefore strongly supports the intention of the governing parties to launch an initiative together with their European partners to establish an international climate club open to all states with a uniform minimum CO_2 price and a joint CO_2 border adjustment.[34]

A 2 Catching Up and Avoiding Technological Gaps

To be able to take full advantage of the new potential for value creation that is emerging in the transformative change, Germany must assert itself as a location for innovation. However, Germany is lagging behind internationally in the development of radically new technologies and their application.[35] Asian countries, along with the USA, are increasingly emerging as providers of such technologies. China, in particular, has caught up internationally in the performance of its R&I system in recent years and is actively working to take a leading role in important future technologies and become the world's leading innovation location.

To take a strong position in global competition and maintain technological sovereignty, it is not only necessary for Germany to catch up with existing technological gaps, but also to become an international leader in future technologies. To this end, Germany should further develop its performance and attractiveness as an innovation location in concert with the other Member States of the European Union (EU) and advance its ambitious R&I policy goals in a division of labour. In addition, innovation partnerships should be promoted at the global level.

Establishing a Monitoring and Advisory Body for Key Enabling Technologies

Key enabling technologies are characterized (cf. chapter B 1) by the fact that they enable, support and promote innovation activities in a large number of other technologies and industries. They generate an above-average broad impact in terms of technologies and industries and thus make a decisive contribution to the transformation of the economy and society. Key enabling technologies can currently be identified in production technologies, materials technologies, bio- and life sciences and digital technologies. While Germany has strengths in production technologies and in the bio- and life sciences, it shows considerable weaknesses in the development of digital technologies. There is a danger of not keeping pace in this increasingly important technology area, which is also having an increasing impact on other key enabling technology areas such as production technologies. Germany is dependent on imports from China, particularly in the area of digital technologies (cf. chapter B 1). The Commission of Experts therefore welcomes the plans of the government parties to push forward the development of key enabling technologies in a targeted manner.[36]

To be able to promote key enabling technologies in a targeted manner, it is necessary to identify them continuously by means of foresight and monitoring measures and to track their development. The Commission of Experts sees the danger that certain industries will be declared key enabling technologies out of particular interests. For instance, the governing parties intend to declare naval submarine and surface shipbuilding a key enabling technology,[37] even though it fails to meet all the criteria for a key enabling technology.

To ensure that the complex task of identifying key enabling technologies is not determined by assertive individual interests, an independent monitoring unit should be commissioned, consisting of several relevant and, if possible, European research institutions. The Commission of Experts also advocates the establishment of an independent strategic advisory body to be entrusted with the evaluation of the results. This advisory body should continuously update a key enabling technologies portfolio and develop recommendations for action for the Federal Government on how to deal with selected key enabling technologies.

Further Promoting Digital Technologies of the Future

In the past, the Federal Government has already recognized the importance of various digital technologies of the future and begun to promote them through strategies or framework programmes.

For example, in November 2018, the then Federal Government adopted a strategy for the promotion of artificial intelligence (AI strategy) and updated it in December 2020.[38] €5 billion were made available for this purpose until 2025, including the funds from the Economic Stimulus and Future Package (Konjunktur- und Zukunftspaket). As of 31 August 2021, almost €3.5 billion has been included in the budgets of the federal ministries, but less than 10 percent of this has been spent.[39] While the exploratory paper of the coalition parties spoke of a new AI strategy to be set up,[40] the coalition agreement does not provide any detailed direction in this regard. The Commission of Experts suggests that the Federal Government continue to press ahead with the AI strategy and develop concepts to use the funds in a targeted manner.[41]

Another example is the framework programme 'Quantum Technologies – from the Basics to the Market' (Quantentechnologien – von den Grundlagen zum Markt), which was adopted in 2018 by the then Federal Government.[42] With funds from the Economic Stimulus and Future Package, a total of around €2 billion is available for funding until 2025.[43] The Commission of Experts takes a positive view of the fact that a quantum computing roadmap was developed by a council of experts[44] and that quantum computers[45] are already being set up at various locations in Germany. It also welcomes the fact that the governing parties are committed to promoting quantum technology in the coalition agreement.[46] The Commission of Experts expects the Federal Government to further develop the framework programme for quantum technologies beyond 2025 and to provide adequate funding.

Further Expansion of the Digital Infrastructure

With the advancing digitalization of the economy and society, the need for digital infrastructure is growing. This promotes innovation and thus has a strong influence on Germany's future and competitiveness. In June 2021, 62.1 percent of households in Germany had a broadband network connection enabling transmission rates of at least 1 Gbit/s.[47] The share was significantly higher in urban areas, with 78.4 percent of all households, than in semi-urban and rural areas, where it was 47.1 and 22.9 percent, respectively.[48] The Digitalization Index 2021 shows that, despite the COVID-19 pandemic, there has been no digitalization surge at all levels for businesses.[49]

As digitalization is making its way into all areas of life, e.g. smart home, autonomous driving (cf. chapter B 2), health (cf. chapter B 4), it is important to have a supply of fast internet not only in conurbations but also in rural areas. The Commission of Experts therefore welcomes the fact that the coalition agreement names a whole bundle of potentially target-oriented instruments to accelerate the expansion of fibre-optic networks and networks for the latest mobile communications standard.[50]

Promoting E-government

By the end of 2022, 575 public administrative services must be offered electronically throughout Germany in accordance with the Online Access Act (Onlinezugangsgesetz, OZG).[51] As of 30 September 2021, only 84 of these administrative services have been digitized and made available online in every municipality.[52] The Standards Control Council (Normenkontrollrat) has determined that the goal of making all administrative services available online by the end of 2022 is no longer achievable.[53] The Commission of Experts therefore welcomes the fact[54] that the new government parties are designating clear responsibilities and finally pushing ahead with the implementation of the OZG and the standardization of structures and processes with a central budget.[55]

Rapidly Creating a High-performance Cloud Infrastructure

A functioning and reliable cloud infrastructure is one of the basic prerequisites for the success of the digitalization of the federal administration. The Commission of Experts therefore welcomes in principle the plans of the government parties to accelerate the expansion of the existing cloud infrastructure[56] towards a multi-cloud solution.[57] Here, concepts are also being drawn up with solutions from established cloud providers.[58] However, the Commission of Experts notes that despite the need for a rapid solution, open source solutions should also continue to be pursued.

Strengthening Cybersecurity

According to the assessment of the Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik, BSI), the threat situation from cyber criminals has intensified over the course of the last year.[59] Recent cyber attacks or security vulnerabilities, e.g. the critical Log4Shell vulnerability in some Java applications that became known in December 2021,[60] have shown that these can limit the sovereignty and ability to act of administration, science and business.[61] The Commission of Experts therefore welcomes the fact that the government parties are planning to focus on cybersecurity as part of a cybersecurity strategy.[62] To bundle skills and expertise, the Commission of Experts suggests that the Agency for Innovation in Cybersecurity (Agentur für Innovation in der Cybersicherheit) be involved and cooperate with the BSI. At the same time, the Commission of Experts criticizes the fact that the coalition agreement contains no statement on the further development of this immensely important agency.[63]

Focus on Promoting the Semiconductor Industry

Semiconductors and microchips have become indispensable in electronic products and thus also in automobiles. The current chip shortage illustrates the relevance of this technology area. It means, for example, that car manufacturers have to cut back on production and that household electrical appliances are not available.[64]

The production of semiconductors is a complex process currently characterized by the international division of labour. Individual countries specialize in certain technologies such as memory chips or processors as well as in certain manufacturing steps such as design or production.[65] The coalition parties plan to promote the semiconductor industry in Germany along the entire value chain.[66] The Commission of Experts states that promotion should focus on selected sub-sectors in which competitive advantages can be achieved jointly with the EU. In addition, the funding should be catalytic, i. e. not permanent. The Commission of Experts welcomes the Federal Government's intention to become more involved at European level in the Important Project of Common European Interest Microelectronics and Communication Technologies.[67]

Harnessing the Innovation and Value Creation Potential of Data

High-quality research data are a central basis for new insights as well as innovations. The Commission of Experts therefore welcomes the fact that the coalition parties want to improve and simplify access to data for research with a Research Data Act and want to further develop the National Research Data Infrastructure and also promote a European Research Data Space.[68] Because the innovation and value creation potential of health data is particularly high, it is necessary to facilitate the use of this data for science (cf. chapter B 4). The Commission of Experts therefore considers the Health Data Use Act (Gesundheitsdatennutzungsgesetz)[69] announced in the coalition agreement to be expedient, which takes into account the high sensitivity of health data. The planned decentralized research data infrastructure can help to improve access and the associated opportunities for use.

The establishment of a data institute planned in the coalition agreement, which is to drive data availability and standardization and establish data trustee models and licences,[70] can support the realization of innovation and value creation potential. However, the Commission of Experts points out that there are already existing competences in research data centres that currently fulfil some of these tasks. Close coordination should therefore take place to avoid parallel structures and to bundle competences.

A 3 Strengthening the Skilled Labour Base Through Education and Training

The proportion of companies whose business activities are hampered by a shortage of skilled workers rose sharply again in all sectors of the German economy in 2021. The lack of skilled workers is a problem especially for small and medium-sized enterprises (SMEs) in industry. Major shortages of skilled workers are emerging in the area of STEM professions.[71] In many professions relevant to the implementation of more climate protection, the foreseeable demand for skilled workers, including in the skilled trades, cannot be met by the currently trained next generation.[72] In order for Germany to be able to realize the innovations and productivity gains required to cope with the ongoing transformations and major tasks of the future, the strengthening of the skilled labour base should be accelerated. To ensure a good supply of suitably qualified workers, schools and tertiary education institutions as well as vocational and continuing education and training must become more efficient, more needs-based and more socially permeable.

Better Teaching of STEM Skills in Schools

Key competences for coping with transformative change must already be developed at school. The Commission of Experts therefore observes with great concern the results of school performance studies, according to which the mathematical and scientific performance of pupils has fallen continuously since 2012. One in five young people does not reach the level of STEM skills that can be considered a viable basis for further education at school or in a profession.[73] As far as digitalization is concerned, additional financial resources from the Federal Government have recently made it possible to achieve improvements in infrastructure. However, many schools lack IT staff[74] to ensure administration and support for teachers.[75] In addition, many teachers are not yet sufficiently qualified to use digital tools in the classroom.[76]

The Commission of Experts therefore supports the plan of the governing parties to convene an education summit[77] to achieve cooperation geared towards ambitious educational goals with the Länder and municipalities within the existing constitutional framework. Since digital skills are a key qualification for mastering the challenges facing society, it also supports the plan to continue the Digital Pact for Schools (DigitalPakt Schule) until 2030[78] and to sustainably improve the digital equipment of schools. However, the provision of digital learning tools must be secured by innovative concepts for teaching, and sufficient staff capacities. This also applies to the planned additional equipment of schools in disadvantaged neighbourhoods via a starting opportunities programme (Startchancen-Programm),[79] which, in the view of the Commission of Experts, could make an important contribution to developing the talents of children and young people from disadvantaged backgrounds. To improve STEM skills, the Commission of Experts recommends that learning content and teaching methods be put to the test, that impending bottlenecks in the supply of qualified teachers in STEM subjects be combated more actively and that the school subject of computer science be expanded.

Ensuring the Quality of Tertiary Education

High-quality higher education is of direct importance for research and innovation. With the Pact for Future Strengthening Study and Teaching (Zukunftsvertrag Studium und Lehre), the Federal Government and the Länder have been providing substantial funds since 2020 to improve study conditions and teaching quality at all tertiary education institutions. The Commission of Experts welcomes the dynamization of these funds as provided for in the coalition agreement.[80] Provided that the Länder go along, this will provide the necessary planning security.

The Commission of Experts also welcomes the announced federal programme 'Digitale Hochschule' (Digital Tertiary Education Institutions),[81] to promote concepts for the expansion of innovative teaching, qualification measures, digital infrastructures and cyber security. Competitively awarded project funds create incentives for innovation. In addition, however, the Commission of Experts once again calls[82] for the Federal Government and the Länder to provide an annual digitalization allowance of €92 per student, which should be made dynamic, in order to permanently improve existing deficits in the conditions for digital teaching across the board.

Making the Dual VET System More Attractive

Dual-system vocational education and training (VET) in a workplace context contributes significantly to Germany's high labour productivity and makes it easier for employees and employers alike to implement innovations and manage transformative change. However, the VET system is undergoing a transformation that the COVID-19 crisis may have accelerated. In 2021, almost 10 percent fewer training contracts were concluded than in 2019. A strong slump in the number of applications, which has been declining for a long time, contributed to this.[83]

The Commission of Experts advises the new Federal Government to make in-company VET more attractive from both the supply and demand sides and thus stabilize it. On the supply side, the support programme 'Ausbildungsplätze sichern' (Securing apprenticeship places), launched in 2020 for companies, should be continued for a limited period of time in view of the particular economic uncertainty that continues to exist. On the demand side, career guidance and counselling measures should be stepped up to boost interest, especially in the VET occupations relevant to managing transformative processes. The Federal Government should also work to ensure that all training regulations are adapted to digitalization. Advice and support for the implementation of digitalization-oriented training should be expanded, especially for SMEs, for example through increased support for training alliances.[84] The Commission of Experts supports the announced pact to strengthen and modernize vocational schools.[85] However, this must be provided with sufficient funds, which should be used primarily for the digitalization of these schools and the qualification of teachers there to teach increasingly complex content and skills.

Strengthening Professional Adaptability Through Continued Training

Transformative change processes increase the demands on professional adaptability and thus also on continuing education and training (CET). The possibilities for subsidizing employers who provide CET to employees in jobs that can be replaced by new technologies and those affected by structural change have been significantly expanded in recent years.[86] Nevertheless, the trend towards more subsidized CET measures has not yet noticeably increased.[87] The Commission of Experts therefore recommends that the existing possibilities within the framework of employment promotion be made better known and that the conditions for obtaining financial support be made simpler and more flexible. On a trial basis, the subsidies to employers to compensate for CET costs should be increased while maintaining an appropriate own contribution by the companies, and the effects of this measure should be evaluated.

The Commission of Experts, on the other hand, is critical of the qualification allowance (Qualifizierungsgeld)[88] planned by the governing parties. This new instrument is intended to enable companies in structural change to keep their employees in the company through qualification. However, it makes the system of CET support by the Federal Employment Agency (Bundesagentur für Arbeit, BA) even more complex, is preconditional because it is tied to a company agreement and can inhibit the mobility of workers necessary to cope with structural change. In this context, the Commission of Experts repeats its call from the Annual Report 2021 to promote preventive bridge solutions, i.e. anticipatory adaptation training for employees for whom continued employment with the previous employer is foreseeably not possible.[89] This requires the cooperation of all relevant stakeholders on the ground with the participation of the BA. The Commission of Experts therefore takes a positive view of the establishment of CET alliances and CET agencies[90] planned by the governing parties and recommends in this context that solutions, which involve adequate financial contributions from both the transferring and the receiving company, be tested and evaluated regionally.[91]

To better cushion structural change, support for employees who seek CET independently of their employer should also be expanded. To this end, it makes sense to provide adequate financial subsidies to cover living expenses during CET. In the opinion of the Commission of Experts, the 'Lebenschancen-BAföG'[92] announced by the governing parties to promote self-determined CET[93] is unsuitable for this purpose, as it is not linked to the prerequisites that the CET funded by it is usable in the labour market and thus contributes to improving individual employment opportunities.

In view of the need for increased lifelong learning, the Commission of Experts welcomes the announcement of the government parties to continue the National CET Strategy.[94] However, the announced new focus on general CET must not lead to vocational CET, which is key to coping with transformative change, falling behind.

A 4 Increasing Innovation Participation

Innovation activities on a broader level are needed if the grand societal challenges are to be met and the new innovation potentials associated with the transformations are to be unlocked in the process. In recent years, there has been a declining trend in innovator rates and a less dynamic start-up activity in the knowledge economy. To counteract these trends, the new Federal Government should improve the conditions for participation in R&I activities with the help of tailored support measures. R&I policy should address a broad group of stakeholders. Traditionally, start-ups and academic spin-offs as well as SMEs come to mind here. However, non-R&D enterprises, which are particularly characteristic of structurally disadvantaged regions, and so-called social enterprises, which address social and ecological problems with entrepreneurial means, should also be given greater attention.

Improving Conditions for Start-ups

Young companies with high growth potential, so-called start-ups, play an important role in the innovation system.[95] The Commission of Experts welcomes the intention of the government parties to adopt a comprehensive start-up strategy and to develop Germany into a leading start-up location.[96] The considerations to improve start-up conditions in general, for example by easing bureaucratic processes and by setting up nationwide one-stop shops for start-up advice, promotion and registration,[97] represent the first welcome steps in the desired direction.

An adequately equipped venture capital market creates good financing conditions for the establishment and successful development of technology companies. The governing parties have announced that they will continue to develop the Future Fund launched by the previous government in 2021.[98] With the modular expansion to include a growth fund and thus the opening to institutional investors, they are following earlier recommendations of the Commission of Experts.[99] With a view to further modular expansions, the Commission of Experts is in favour of also developing a module for impact investing, which, in addition to the goal of generating returns, also pursues social, environmental and climate-related goals that can be measured in the long term.[100] The Commission of Experts supports the objective of the governing parties to increase the share of female founders in the digital sector.[101] It proposes to develop a venture capital module specifically for female founders with resources from the Future Fund and to provide scholarship funds in the EXIST programme alongside this.

The planned facilitation of initial public offerings (IPOs), especially for growth companies and SMEs, as well as the improvement of the conditions for employee participation in start-ups are to be seen as positive.[102]

In the coalition agreement, spin-offs from science receive special attention. The culture of spin-offs at tertiary education institutions and non-university research institutions should be strengthened and the cultural change required for this should be accompanied by science entrepreneurship initiatives.[103] Evaluation results should be taken into account in the development of the corresponding measures.[104] Furthermore, the coalition agreement envisages providing tertiary education institutions with funds for the creation of a start-up infrastructure for technological and social entrepreneurship.[105] The Commission of Experts considers it essential to considerably professionalize the start-up and transfer infrastructure that generally already exists at tertiary education institutions, to structurally supplement it with makerspaces and similar formats, and to debureaucratize the processes implemented there.

Aligning R&I Funding with Potential

The coalition agreement provides for all federal funding programmes to be regularly reviewed for their regional impact and for the results to be published in a periodic equivalence report.[106] This monitoring is intended to be a binding basis for the further development of all funding programmes. The Commission of Experts sees the danger that this approach will mix up R&I policy and structural policy goals. To avoid this, it believes that a differentiated, potential-oriented approach is required.[107]

In the opinion of the Commission of Experts, the focus of R&I policy must continue to be on the promotion of excellent innovation projects, even if not all regions will benefit equally.

In the course of transformative change, new regional innovation ecosystems will emerge, through which development opportunities for structurally weak regions can arise. The Commission of Experts considers the promotion of such regional innovation ecosystems, as is currently being pursued within the framework of the Innovation and Structural Change programme family (Programmfamilie Innovation und Strukturwandel),[108] to make sense if these funding formats are selected according to criteria of excellence.

The Commission of Experts sees a danger in the government parties' intention to prioritize support for the expansion and establishment of non-university institutions in regions that are currently under-equipped,[109] and that decisions will not be made on the basis of topical suitability. It therefore advocates making location decisions based on the potentials available in the regions and the thematic strengths already developing – in the sense of the smart specialization approach.[110]

The increase in funding announced in the coalition agreement for the Joint Task of Regional Economic Development (Gemeinschaftsaufgabe Regionale Wirtschaftsentwicklung) for Innovation Promotion, Digitalization, Operational Productivity Targets, Sustainability and Decarbonization[111] takes into account the Commission of Experts' call, expressed in the Annual Report 2020, for structural policy to be even more innovation-oriented than before.[112]

Avoiding Distortions in Innovation Competition

The governing parties have expressed the will to establish innovation regions based on the British model,[113] by creating privileged framework conditions for R&I activities, such as tax breaks, at individual locations. The Commission of Experts is extremely critical of this idea because it creates serious distortions in innovation competition. The goal should be that attractive overall conditions for R&I activities prevail in all regions. The emergence of lighthouses can be supported by promoting clusters – as is currently being done within the framework of the Clusters4Future Initiative (Zukunftscluster-Initiative).[114]

Making Public Procurement Innovation-oriented

Public procurement can provide important impulses for innovation activities and participation, given the considerable volume of procurement. The governing parties have agreed to make public procurement and awarding more economic, social, ecological and innovative.[115] The Commission of Experts is again in favour of making awarding practice more innovation-oriented and establishing a 'priority for the innovative offer' as an award criterion for this. However, such a criterion should include a careful weighing of the expected positive innovation effects against the potential additional costs of procurement.

A 5 Developing Agile Governance Structures

In its Annual Report 2021, the Commission of Experts emphatically pointed out that the R&I policy tasks and missions associated with the upcoming transformative change require agile policy action.[116] The Federal Government was called upon to develop corresponding governance structures for the ministries and administrations, on the basis of which not only fast and flexible action is taken, but long-term decisions are also proactively prepared, relevant stakeholders are involved at an early stage, and measures and structures implemented are continuously reviewed and adapted if necessary. In this context, isolated measures, especially agency concepts, have been discussed and proposed during the federal election campaign. The Commission of Experts has commented on this in policy briefs.[117] It welcomes the announcement by the governing parties to overcome a silo mentality and to endow permanent interdepartmental and interagency agile project teams and innovation units with concrete competences.[118]

Acting Agilely in Digital Policy

The digital transformation is proceeding very slowly in Germany (cf. chapter A 2) and must therefore be accelerated significantly in the new legislative period. Despite all efforts, the previous structures and processes within the Federal Government have not succeeded in igniting the necessary dynamism in the international competition for digitalization.[119] In the run-up to the coalition negotiations, the Commission of Experts advocated driving forward digitalization with a new type of ministry and equipping it with structures and processes that enable agile policy action.[120] Instead of establishing a separate digital ministry, the new Federal Government has expanded the responsibilities of the previous Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur, BMVI), which is underlined by the renaming of the ministry as the Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr, BMDV). At the same time, many tasks related to digitalization remain in other departments. In this new structure, it is necessary to coordinate the digital policy activities of the various ministries more tightly than before and to align them with each other. In addition to the responsibilities of the various ministries, the interfaces must also be clearly defined and structurally anchored through corresponding interdepartmental project teams or task forces.

Rapidly Improving Conditions for SprinD

With the establishment of the Federal Agency for Disruptive Innovation (SprinD), a completely new funding concept was institutionalized in 2019, which for the first time focuses on the promotion of radically innovative technologies and processes. SprinD's activities are aimed at transferring results from (basic) research, the implementation of which is associated with high risks and at the same time high investment requirements, into practical application. To be able to cope with its specific tasks, SprinD was given an institutional structure that is clearly different from the structures of the ministries and project executing agencies. The Commission of Experts has expressly welcomed the establishment of SprinD and calls on the Federal Government to swiftly and effectively implement the improvement of the legal and financial framework conditions for SprinD[121] announced in the coalition agreement. To this end, for example, leeway under procurement law, budgetary law and subsidy law must be more courageously exploited and, if necessary, expanded. It is important that SprinD can act independently of operational control by the ministerial bureaucracies.

Do Not Rely on Agency Solutions as a Panacea

In addition to SprinD, the coalition agreement outlines two new agencies to promote innovation activities.

The establishment of a German Agency for Transfer and Innovation (Deutsche Agentur für Transfer und Innovation, DATI) is planned with the aim of boosting application-oriented research and transfer as well as regional and supraregional innovation ecosystems.[122] According to the coalition agreement, this agency is to promote social and technological innovations, particularly at universities of applied sciences (UAS) and small and medium-sized universities. According to the government parties, existing funding programmes for UAS are to form the basis for DATI and be expanded. There are also plans to bundle relevant funding programmes from various ministries under the umbrella of DATI. The Commission of Experts views the establishment of such an agency with scepticism. The tasks assigned to DATI largely coincide with those for which the project management agencies are responsible. The Commission of Experts is of the opinion that the establishment of new agencies only makes sense if they take on tasks in the German R&I system that were not previously covered, neither by state funding programmes and research institutions nor sufficiently by the involvement of private stakeholders, and for the fulfilment of which institutional requirements are necessary that do not yet exist.[123] The Commission of Experts cannot recognize this in the case of a DATI. It would be more targeted to reform the project-executing agency model with the aim of raising efficiency and agility potentials.

The governing parties are planning to expand the promotional bank KfW as an innovation and investment agency – especially for AI, quantum technology, hydrogen, medicine, sustainable mobility, bioeconomy and circular economy. The Commission of Experts believes it makes sense to strengthen KfW's function as a promotional bank that facilitates investments in innovative technologies and acts as a co-venture capital provider. However, it is opposed to expanding KfW into an agency that engages in classic R&I promotion.

Integrating Evaluations and Policy Learning More Strongly into Processes

The Commission of Experts has already spoken out several times in favour of integrating policy learning more strongly into R&I policy processes.[124] A policy of experimentation and evaluations are important cornerstones here.

Insights into the effect of alternative regulatory approaches can be gained through the establishment of real-world laboratories. The Commission of Experts therefore considers the creation of a legal basis for real-world laboratories announced by the governing parties to be sensible.

Evaluations of R&I policy measures are important for generating learning effects for future R&I funding measures. The significance and thus the usefulness of these evaluations also depend on what information and data are available for the evaluations. The Commission of Experts recommends that evaluation should already be planned when designing R&I funding measures and that the institutions carrying out the evaluations should be given access to relevant information and data at an early stage. In order for evaluation results to be of greater value for policy learning and policy making, awareness of the benefits of evaluations should be raised. This requires a better understanding of how to conduct evaluations professionally, as well as a positive error culture that enables learning from failure.[125]

In recent decades, R&I policy has become increasingly diverse and complex. The current funding measures are based on various policy approaches pursued in parallel by different ministries.[126] Against this background, the Commission of Experts advocates not only evaluating the individual R&I policy measures individually, but also initiating an evaluation of the entire funding architecture. In this context, redundancies in R&I funding should be determined and funding gaps identified.[127]

B

CORE TOPICS 2022

B 1 Key Enabling Technologies and Technological Sovereignty

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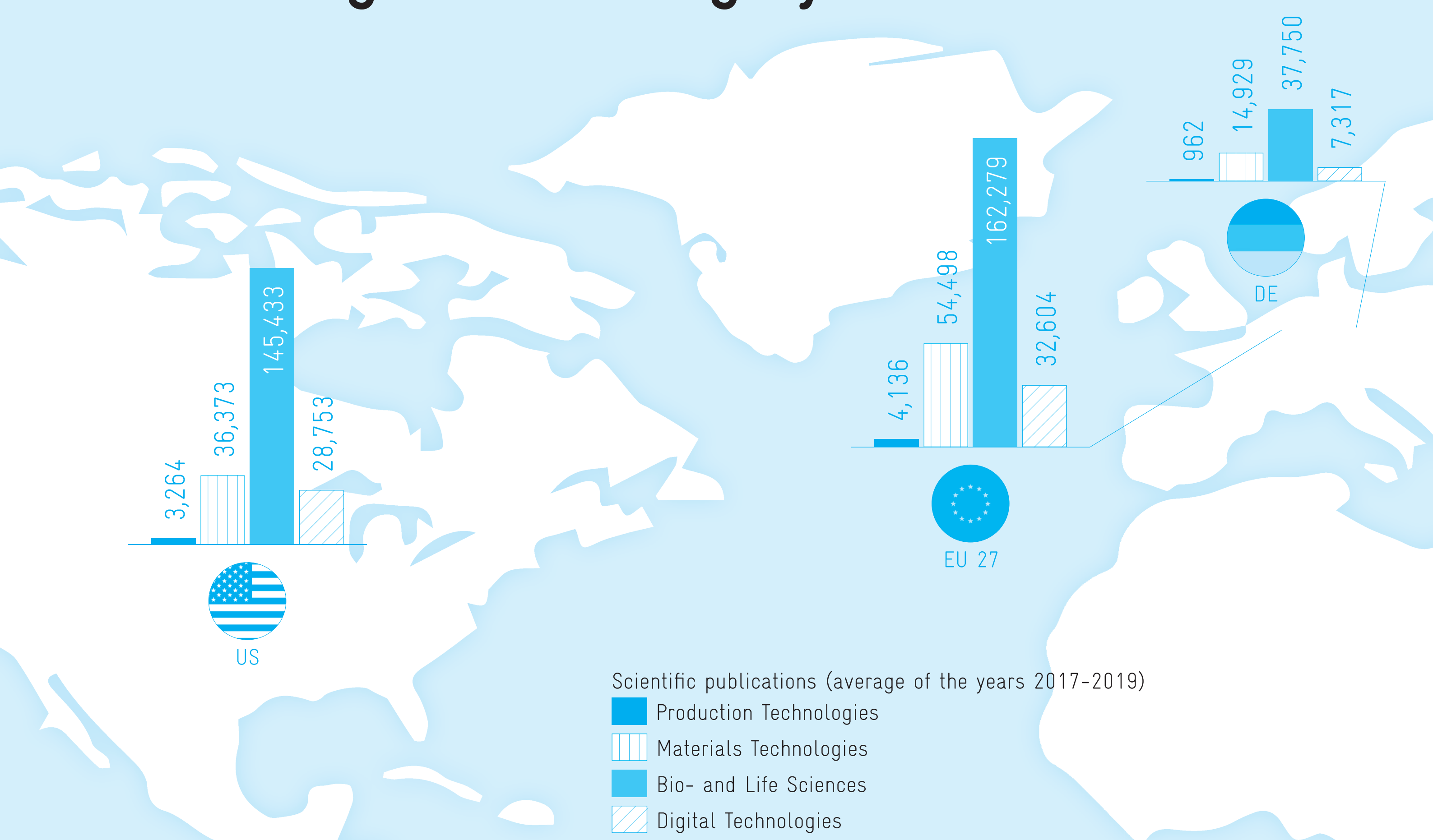
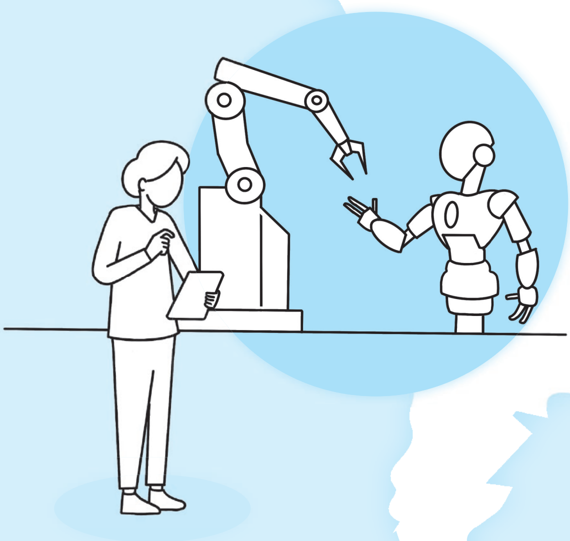


Production Technologies

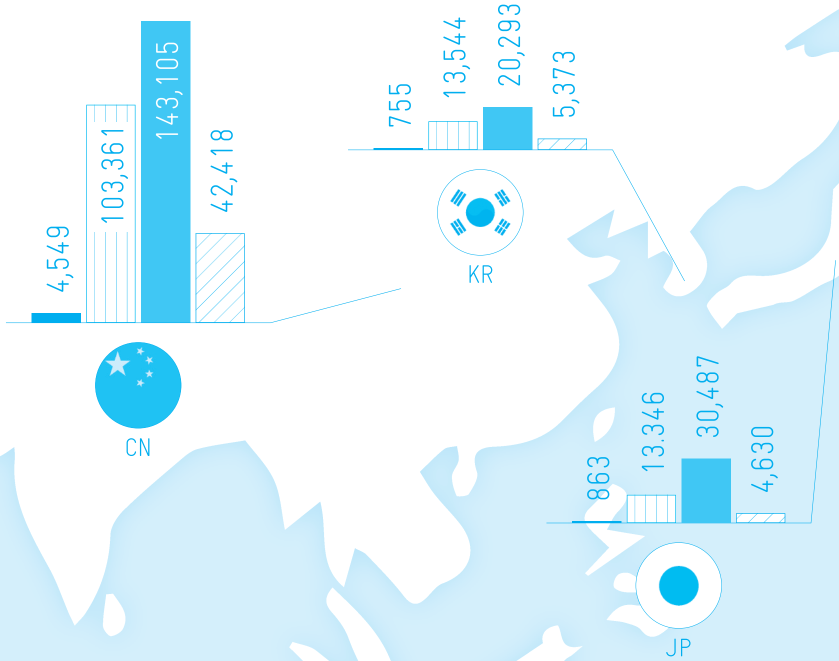
Advanced Manufacturing, Robotics, Photonics



Materials Technologies

New Materials, Nanotechnologies

Key enabling technologies open up high potentials for a prosperous technological and economic development of a national economy and thus for prosperity. They are of central importance for current and future value creation activities. Unique selling propositions and innovations in key enabling technologies contribute to the competitiveness of an economy's companies in these technologies. For this reason, key enabling technologies have increasingly moved into the focus of politics. In order for a national economy to be able to act with technological sovereignty in established as well as future key enabling technologies and not fall into welfare-reducing dependencies, political decision-makers see themselves compelled to develop suitable strategic concepts.



Bio- and Life Sciences

Bioeconomy, Life Sciences

Digital Technologies

Microelectronics, Artificial Intelligence, Internet of Things, Digital Security Technologies, Big Data, Digital Mobility Technologies

B 1 Key Enabling Technologies and Technological Sovereignty

Key enabling technologies are technologies that play key roles in technological and economic developments. One of these roles results from the importance of a key enabling technology for the innovative further development and application of other technologies (enabler function). For example, powerful control chips play a particularly important, often irreplaceable role in many areas of modern production (Industry 4.0), in the provision and further development of new energy and mobility concepts, and increasingly in domestic consumption (smart home). These technologies also play a key role through their central contribution to the emergence and development of large and dynamic global markets. By 2024, for example, global sales of the artificial intelligence (AI) market are expected to exceed the US$500 billion mark, with a five-year compound annual growth rate of 17.5 percent and total sales of US$554.3 billion.[128] In addition, key enabling technologies are seen as playing a key role in important transformation processes in the economy and society. For example, sustainability-relevant technologies in the fields of bioeconomy or high-quality healthcare can come into play in addressing the grand societal challenges and pursuing the Sustainable Development Goals.[129]

Key enabling technologies open up high potentials for a prosperous technological and economic development of a national economy and thus for prosperity. They are of crucial importance for current and future value creation activities. Unique selling propositions and innovations in key enabling technologies contribute to the competitiveness of companies and other stakeholders in the R&I system of an economy. Finally, they open up the possibility for an economy to actively shape global economic and social transformation processes and to contribute to the solution of the grand societal challenges.

To be able to pursue these goals in a self-determined manner and to use the associated potential, an economy must have a high degree of technological sovereignty in dealing with key enabling technologies. If an economy loses its international connection and thus its sovereignty, dependencies can arise that reduce welfare and are difficult to eliminate in the short or medium term.

For this reason, key enabling technologies have increasingly become the focus of political decision-makers, who must develop suitable strategic concepts so that an economy can act with technological sovereignty in established as well as future key enabling technologies and does not fall into welfare-reducing dependencies.

B 1-1 Key Enabling Technologies and Their Relevance for Technological Sovereignty

Key Enabling Technologies Defined by Three Criteria

The definition of the concept of key enabling technologies lacks consistency and precision both in scientific literature and in political discussion.[130] The following three criteria[131] are proposed in the existing literature[132] for the identification of key enabling technologies:

1) Broad applicability in a variety of technology areas or economic sectors

2) Strong, non-substitutable complementarity to a variety of other technologies

3) High potential for performance enhancement in a key enabling technology itself and in its application areas

Criteria one and two relate directly to the application side of key enabling technologies, that is, a broad application in other technologies, and very often without technological alternatives. Criterion three focuses on the innovation potential of a key enabling technology and its application technologies.

In R&I policy and economic policy practice, the classification of a technology as a key enabling technology is not systematic and definition-driven but results discursively from the political processes. An instrumentalization of the concept of key enabling technologies for the enforcement of particular interests cannot be ruled out with such an approach. To avoid this, clear criteria, corresponding to the three mentioned above, must be used in the political process to classify a technology as a key enabling technology.

Portfolio Analysis of Key Enabling Technologies Important

A portfolio analysis is important for determining the international position of an economy in the development and use of established and future key enabling technologies. The established key enabling technologies to be considered can be identified based on the criteria mentioned above. In the case of future key enabling technologies, the extent to which a technology can be expected to fulfil these criteria in the future must be examined. The identification of a future key enabling technology in the early phase of its development is empirically difficult and associated with a high degree of uncertainty. One possible approach is a dialogue-based strategic foresight process[133] that involves experts from science, politics and business and is led by a strategic advisory body.[134]

This strategic advisory body can also be given the task of building and developing a portfolio of established and future key enabling technologies. This task would include regularly reviewing the classification of a technology as a key enabling technology within the portfolio.

The systematic development of a portfolio can help to identify key enabling technologies at an early stage by means of a long-term perspective and to support their development with suitable measures if necessary. In the case of established key enabling technologies, weaknesses and resulting dependencies can be identified in an international comparison.

Mastery and Availability Essential for Technological Sovereignty

The term technological sovereignty has been used in German politics since around the beginning of the 2010s and initially focused on digital technologies and digital security. Over time, the term was expanded to include all areas of technology. Digital technologies and security aspects are now discussed under the term digital sovereignty, which is considered an essential component of a country's technological sovereignty.[135]

In the literature, the concept of technological sovereignty is described and defined quite differently.[136] A suitable definition starts at the level of a national economy and refers to a single technology. The definition of the Commission of Experts builds on the Fraunhofer ISI's definition[137] and adapts it accordingly:[138]

> A national economy has technological sovereignty if it can itself provide and further develop a technology it deems critical for its welfare, competitiveness and ability to act, and if it can participate in its standardization and is able to apply and to source this technology from other economic areas without one-sided structural dependency.

Key enabling technologies, which by definition contribute significantly to welfare and competitiveness in a national economy and occupy central, system-relevant positions, are undoubtedly among the technologies for which the question of the technological sovereignty is of particular relevance. If the technology is not sufficiently available, welfare-reducing bottlenecks can occur – especially in crisis situations.

Technological sovereignty results, on the one hand, from the degree to which a national economy masters the application and use of a certain technology and, on the other hand, from the degree to which this technology is available to a national economy for further use. The dimension of mastery measures the knowledge and skills that exist within a national economy with respect to a particular technology. The dimension of availability measures the extent to which a national economy has a particular technology at its disposal for further use, whether through its own production or through full or partial procurement from outside via international trade.

Technological Sovereignty Threatened by Gaps in Key Enabling Technologies

How the mastery of a key enabling technology can become a critical factor can be explained with a model of technological knowledge building.[139, 140] According to this model, the process of building knowledge in a particular technological field takes place in a cumulative, self-reinforcing way. This means that further knowledge growth in a technology area depends on the level achieved so far in that area. In relation to a key enabling technology and the innovation competition between countries, this mechanism implies that initially existing differences in technological knowledge increase. As a result, a growing technological gap[141] builds up between countries.

How this development affects the two dimensions of technological sovereignty of an economy is illustrated by the example of a single key enabling technology as follows: regarding the dimension of mastery of a technology, the leading economy in a key enabling technology always has a high or complete technological sovereignty. As the technological gap increases, however, the degree of mastery of this key enabling technology decreases step by step for the technologically following economy, and its technological sovereignty declines.

However, this decline in sovereignty can be compensated for by the following economy taking advantage of the international division of labour and importing the latest version of this key enabling technology and the associated application expertise from the technologically leading economy. Technological sovereignty would thus be secured for this economy in terms of the dimensions of availability and mastery of the technology. Yet this approach implies that the comparative disadvantages for the following economy increase as the technological gap grows and its terms of trade deteriorate.[142] Accordingly, the import of the key enabling technologies, including application expertise, becomes increasingly expensive, with the consequence that both the degree of availability and the degree of mastery decrease. In this way, the technological sovereignty of the following country is continuously reduced and its dependence on foreign countries increases.

If the examination is extended to several or very broadly positioned key enabling technologies, then it is conceivable that economies specialize in certain key enabling technologies and build up comparative advantages in them over other economies. In this context of a portfolio of key enabling technologies, the question of technological sovereignty in a particular key enabling technology plays a lesser role. Accordingly, economies can each specialize in key enabling technologies and are then mutually dependent on each other for key enabling technologies, making unilateral dependencies less likely.

An economy's involvement in foreign trade is determined by its comparative advantages and disadvantages in relation to other countries. The concept of comparative advantage can be divided into two types: static and dynamic comparative advantage. Static comparative advantages are due to contextual factors, such as natural conditions; they cannot be influenced or can hardly be influenced. Dynamic comparative advantages, on the other hand, are due to changeable factors. These include technologies that can be improved and developed through technological change and innovation.

An economy that specializes in areas with existing static comparative advantages in such a way that key enabling technologies must be imported from abroad runs the risk of losing technological sovereignty in one or more key enabling technologies due to increasing technological gaps and thus becoming dependent.

One way out of this situation is to stop specializing in areas with existing static comparative advantages. Rather, it makes sense to pursue the development of one's own comparative advantages in key enabling technologies with appropriate funding measures. This 'wrong' specialization from a static point of view is initially associated with welfare-reducing effects.[143] In a dynamic and long-term perspective, however, these can be overcompensated by welfare gains resulting from comparative advantages in key enabling technologies that have been built up in the meantime.[144] South Korea in the 1980s is a good example of this.[145] Its very successful industrialization and its way into the group of technologically leading economies are based precisely on the fact that it did not rely on existing static comparative advantages in rice cultivation and other technologically less demanding areas. The development towards technology- and knowledge-intensive sectors and industries, pushed by the state and supported by intensive promotional measures, has enabled the country to establish comparative advantages in these demanding technology areas after a certain period of time.

B 1-2 Germany's Positioning in Current Key Enabling Technologies

Current Key Enabling Technologies Very Heterogeneous

The Commission of Experts points out that identifying key enabling technologies is a complex and controversial undertaking. For this reason, the Commission of Experts uses for this chapter a study[146] commissioned by it, which employs a selection of key enabling technologies for its analyses that has already been prepared for monitoring and strategy papers at the European and German levels.[147] In this study, 13 individual technologies (see figure B 1-1) were identified that can be assigned to four thematically overarching key enabling technology areas: production technologies, materials technologies, bio- and life sciences, digital technologies.

Since the sectors and products in which a key enabling technology is used play only a minor role in the classification of a technology as a key enabling technology and in the technological sovereignty of a country, the selected key enabling technologies are not considered from an application standpoint in the following. Accordingly, the technologies are analyzed below in terms of how intensively they are being researched and developed and how international trade in them is taking shape. This empirical study is thus based on a supplier-side characterization of key enabling technologies.

First, it is shown whether the worldwide inventions assigned to a key enabling technology, measured in terms of patent applications, originate predominantly from a few or from many different sectors; it is thus a question of the breadth of the development activities associated with it.[148] In addition, it is shown to what extent the worldwide patent applications that can be assigned to a key enabling technology are limited to a clearly defined field of technology or are broadly distributed across different fields of technology.[149]

In figure B 1-1, the key enabling technologies are arranged according to these two dimensions and compared with each other.[150] A heterogeneous structure emerges. For example, while big data technology is being further developed by companies in many sectors, its technological basis is comparatively specific. Microelectronics, on the other hand, is developed by companies from only a few sectors, with a technological base of medium breadth. Advanced manufacturing and new materials technologies are characterized by both a comparatively broad technological base and development activities in comparatively many sectors.[151]

Indicators for International Comparison

Indicators from the areas of research (scientific publications) and development (transnational patent applications), trade (trade balances and specializations) and standard setting (participation in standardization bodies) can represent Germany's position in an international comparison.[152] The degree of mastery of a key enabling technology can be estimated based on publications and patent applications. Trade balances provide information on their availability. Standard-setting activities allow conclusions to be drawn about both the mastery and availability of key enabling technologies.

Scientific Publications: China Particularly Dynamic

To determine Germany's position in an international comparison of research on key enabling technologies, scientific publications worldwide published from 2000 to 2019 are considered.[153] Since changes over time and thus changes in position are of interest, the mean values of the first three years of the period under consideration (2000-2002) and those of the last three years (2017-2019) were calculated and compared. The change factor indicates how the publication figures of the last three years relate to the publication figures of the first three years.

The difference in the change factors between two countries can be used to assess how the gap, in this case the scientific gap, between two countries has developed. For example, if one country lagged

Fig. B 1-1 Development activities and technological basis

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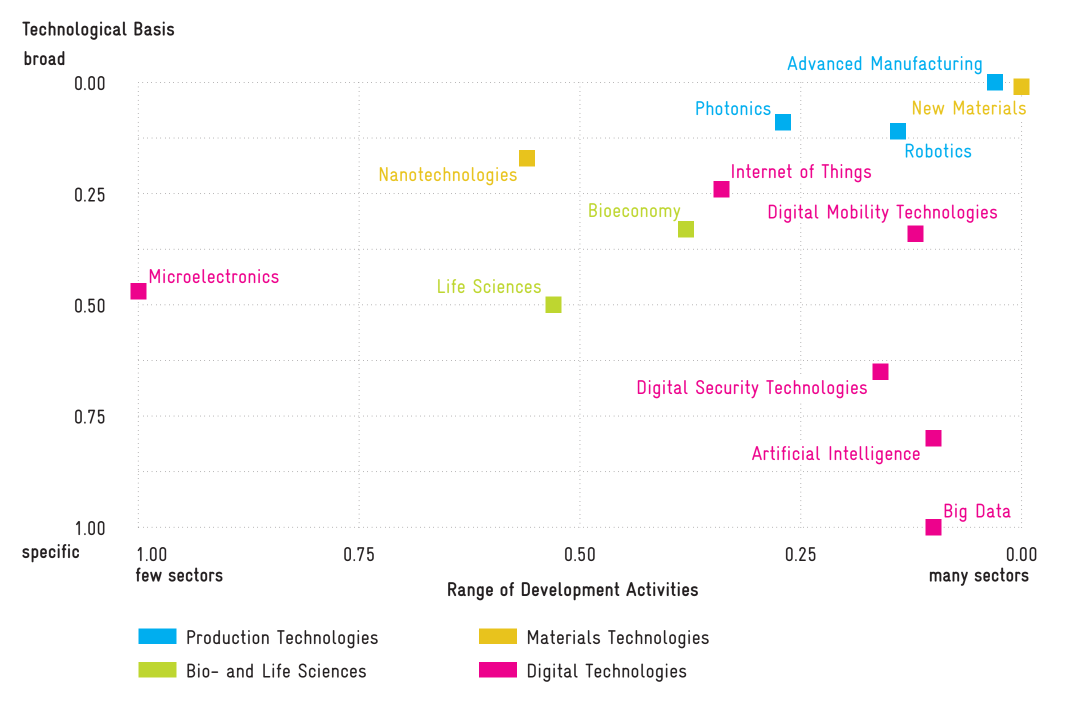

Illustration of the 13 individual technologies based on the breadth of development activities and the technological basis. Legend: With a value of 0.1, Big Data has a relatively broad range of development activity (corresponding technologies are being developed in many sectors). With a value of one, Big Data has a very specific technological basis. Source: Own representation based on Kroll et al. (2022).

behind another in absolute publication numbers but had a higher change factor, the lagging country could narrow the scientific gap over time or possibly even overtake the initially leading country. However, if the change factor of the leading country is greater than that of the lagging country, then the scientific gap between the two countries has widened.

Figure B 1-2 demonstrates that China,[154] the USA and the EU 27 dominate publication activities in all four key enabling technology areas at the current margin. The rapid increase in publication activity in China stands out. Although Germany and other countries have also significantly increased their publication volume, none have done so to a comparable extent. In the area of digital technologies, for example, Germany was able to increase its publication volume by a factor of 3.4, but China by a factor of 17.5. In less than 20 years, China has thus succeeded in overtaking the USA and the EU 27 in the fields of digital technologies, materials technologies and production technologies, and in catching up in the field of bio- and life sciences.[155]

Germany occupies a position in the midfield in all key enabling technology areas that is commensurate with its size. In terms of the change factor, it is generally on par with the European countries and the USA. Compared to South Korea and China, which have significantly higher change factors, Germany's initially advantageous position deteriorates or turns into a following position. A strong position at the top is only possible for Germany together with the other EU 27 countries.

The six individual technologies in the field of digital technologies are presented below. This detailed analysis is justified by the special role of digital technologies. They are increasingly having an impact on almost all other technology areas. As a driving force, they have a pronounced cross-sectional effect, they initiate or accelerate development processes in other technology areas.

According to the change factor, publication activity in Germany is developing at a similarly dynamic pace in all individual digital technologies (see figure B 1-3) as in the other Western countries of

Fig. B 1-2 Mean value of publications in key enabling technology areas for selected countries and regions 2000–2002 and 2017–2019

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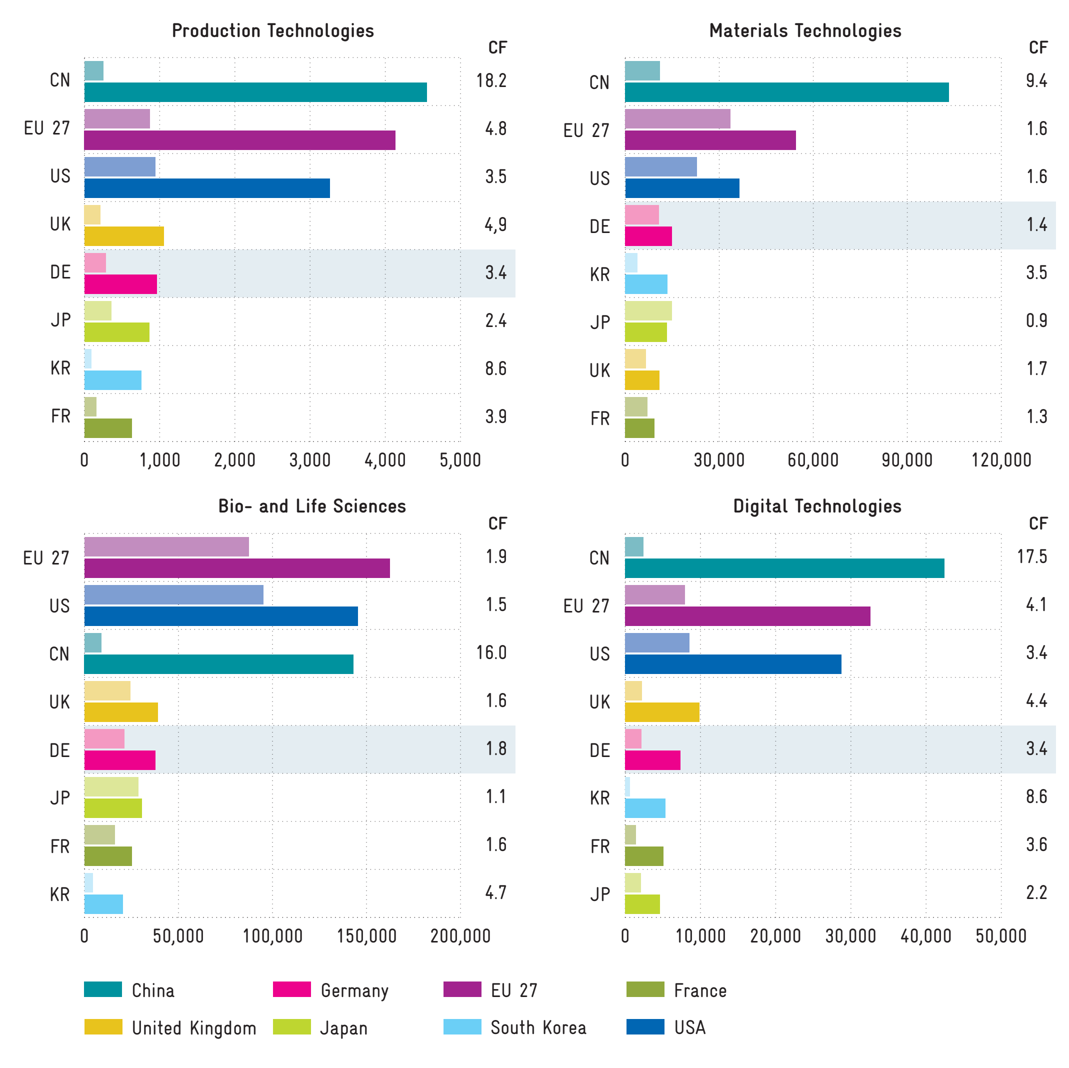

The lighter shade of colour shows the average number of publications for the years 2000 to 2002, the darker shade that for the years 2017 to 2019. The sorting and thus the order of the countries within each key enabling technology area follows the mean values from 2017 to 2019. The change factor (CF) indicates how publication figures for the last three years relate to publication figures for the first three years. A change factor smaller than one means a decrease and a change factor larger than one means an increase in publication numbers in the period under consideration. A change factor of one means that the publication numbers have not changed between the periods under consideration.
Source: Own representation based on Kroll et al. (2022)

comparison. In this detailed analysis, China's strong position is once again noticeable, as it is the leading nation in all digital technologies, with the exception of digital security.

Patent Applications: Mixed picture in Germany

Transnational patent applications[156] in the period from 2000 to 2018 can be used as an indicator for innovations in the application of key enabling technologies.[157] Here, too, the mean values of the first three years of the period under consideration (2000-2002) and those of the last three years (2016-2018) were calculated and compared. The change factor indicates how the patent numbers of the last three years relate to the patent numbers of the first three years. As with the change factor for publications, this can be used in country comparisons to interpret the development of technological gaps based on patents.

Fig. B 1-3 Mean value of publications in digital technology areas for selected countries and regions 2000–2002 and 2017–2019

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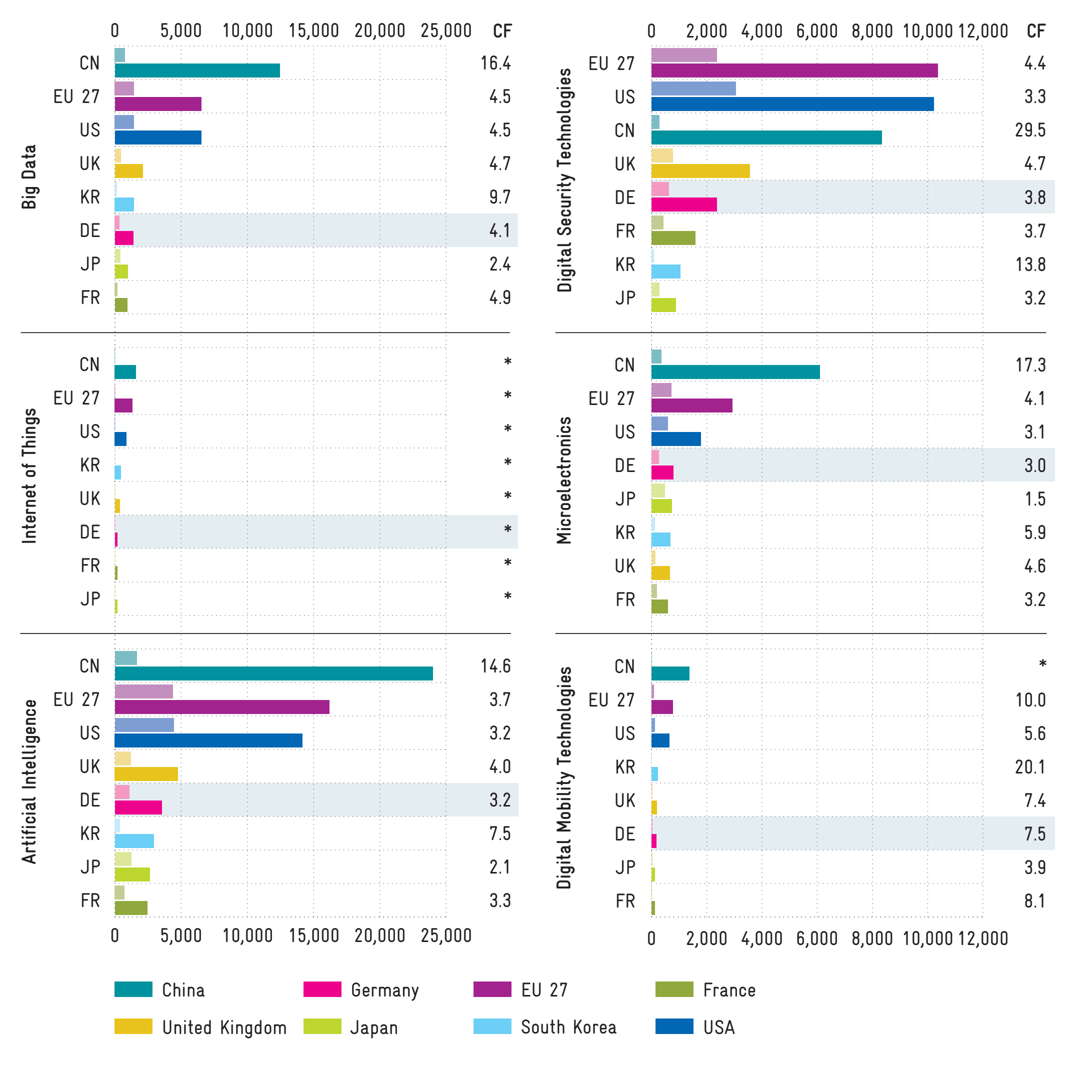

The lighter shade of colour shows the average number of publications for the years 2000 to 2002, the darker shade that for the years 2017 to 2019. The sorting and thus the order of the countries within each technology area follows the mean values from 2017 to 2019. A single publication can be assigned to several individual technologies for reasons of content. The change factor (CF) indicates how the publication figures of the last three years relate to the publication figures of the first three years. A change factor smaller than one means a decrease and a change factor larger than one means an increase in publication numbers in the period under consideration. A change factor of one means that the publication numbers have not changed between the periods under consideration. * are used when the change factor takes on extreme values due to a minor initial value.
Source: Own representation based on Kroll et al. (2022).

The overview shows that especially in the Asian countries (Japan, China, South Korea) patenting activities have increased strongly, while they have decreased in some Western countries (see figure B 1-4). In Germany, this concerns the key enabling technology areas of materials technologies as well as bio- and life sciences.

Germany's patent applications in the key enabling technology areas of production and materials technologies as well as bio- and life sciences are in the middle of the field. Japan, the EU 27 and the USA top the list. China follows in fourth place and also shows a very dynamic development here. In terms of the change factor, Germany is again at a similar level to the other Western countries; however, the significantly higher factors for China, Japan and South Korea show that Germany is increasingly lagging behind in terms of technology. In production technologies and, to a lesser extent, in the bio- and

Fig. B 1-4 Mean value of transnational patent applications in key enabling technology areas for selected countries and regions 2000–2002 and 2016–2018

Download Data

The lighter shade of colour shows the average number of patent applications for the years 2000 to 2002, the darker shade that for the years 2016 to 2018. The sorting and thus the order of the countries within each key enabling technology area follows the mean values from 2016 to 2018. The change factor (CF) indicates how patent application figures for the last three years relate to patent application figures for the first three years. A change factor smaller than one means a decrease and a change factor larger than one means an increase in patent application numbers in the period under consideration. A change factor of one means that the patent application numbers have not changed between the periods under consideration.
Source: Own representation based on Kroll et al. (2022).

life sciences, Germany is still doing quite well in this respect.

In the key enabling technology area of digital technologies, China and South Korea have developed particularly dynamically. Japan and the USA are in the lead, followed by China.

A detailed examination of the individual digital technologies (see figure B 1-5) shows that German patent applications increased moderately in all individual technologies except microelectronics. There was a slight decline in microelectronics. A comparison of the change factors shows that Germany has lost its technological lead to China, South Korea and to some extent also Japan, or that the gap to these countries has widened. The rise of China is striking in this context. China is to be found in the top three places in all individual technologies, with the exception of digital mobility,

Fig. B 1-5 Mean value of transnational patent applications in digital technology areas for selected countries and regions 2000–2002 and 2016–2018

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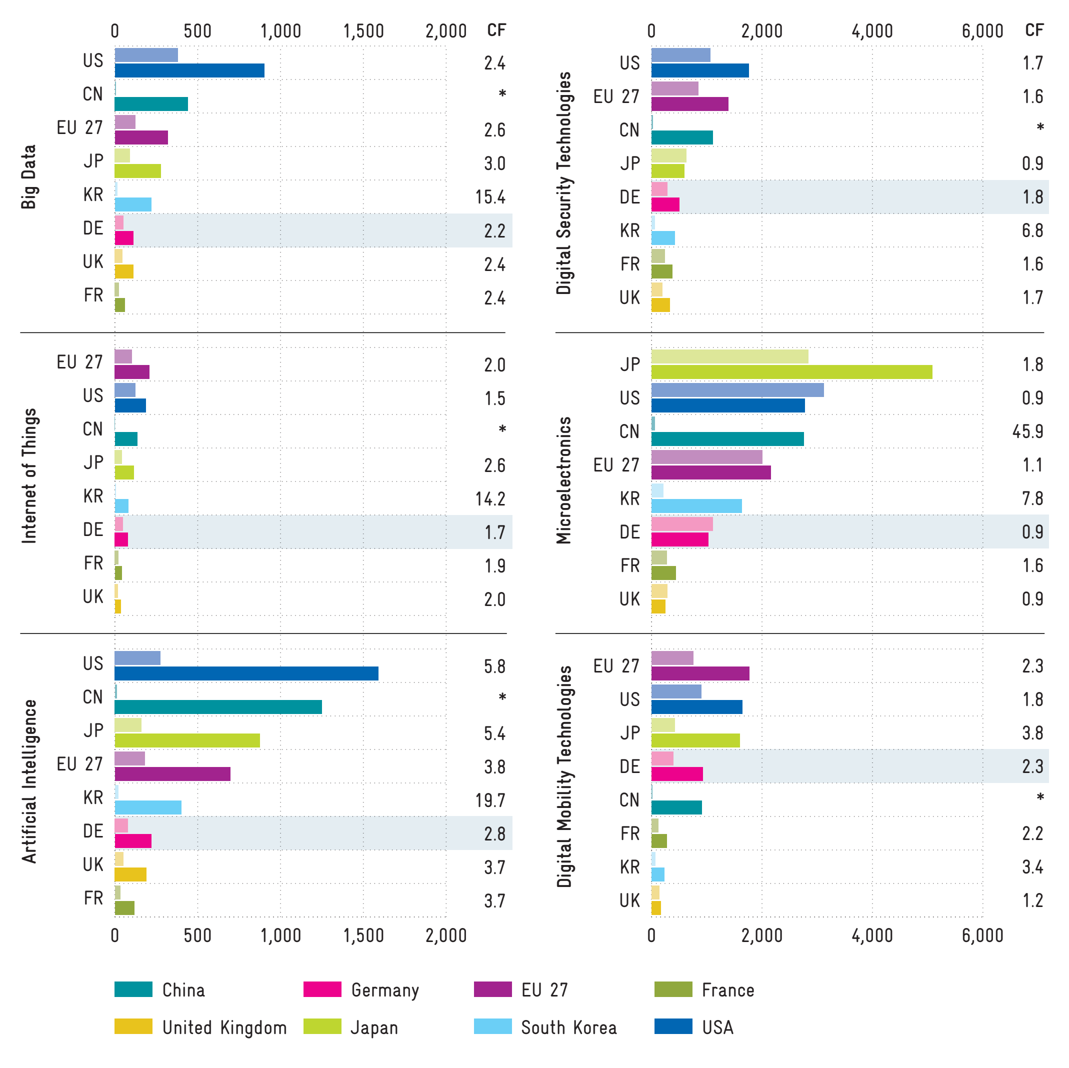

The lighter shade of colour shows the average number of patent applications for the years 2000 to 2002, the darker shade that for the years 2016 to 2018. The sorting and thus the order of the countries within each technology area follows the mean values from 2016 to 2018. A single patent can be assigned to several individual technologies for reasons of content. The change factor (CF) indicates how patent application figures for the last three years relate to patent application figures for the first three years. A change factor smaller than one means a decrease and a change factor larger than one means an increase in patent application numbers in the period under consideration. A change factor of one means that the patent application numbers have not changed between the periods under consideration. * are used when the change factor takes on extreme values due to a minor initial value.
Source: Own representation based on Kroll et al. (2022).

although it has the lowest initial values compared to the other countries.

Relative Trade Balance: Germany Weak in Digital Technologies

The trade balance provides insights into the export strength of an economy. A positive trade balance occurs when exports exceed imports. Figure B 1-6 shows the relative trade balance[158], defined as the percentage surplus of exports over imports, for Germany from 2007 to 2019 in the four key enabling technology areas.[159]

This indicator shows that Germany has relative export strength in the key enabling technology areas of production technologies and materials technologies over the entire period under study, i. e. it is a net exporter. This relative export strength is most pronounced in production technologies. In the key

Fig. B 1-6 Germany's relative trade balance in the key enabling technology areas 2007–2019 in percent

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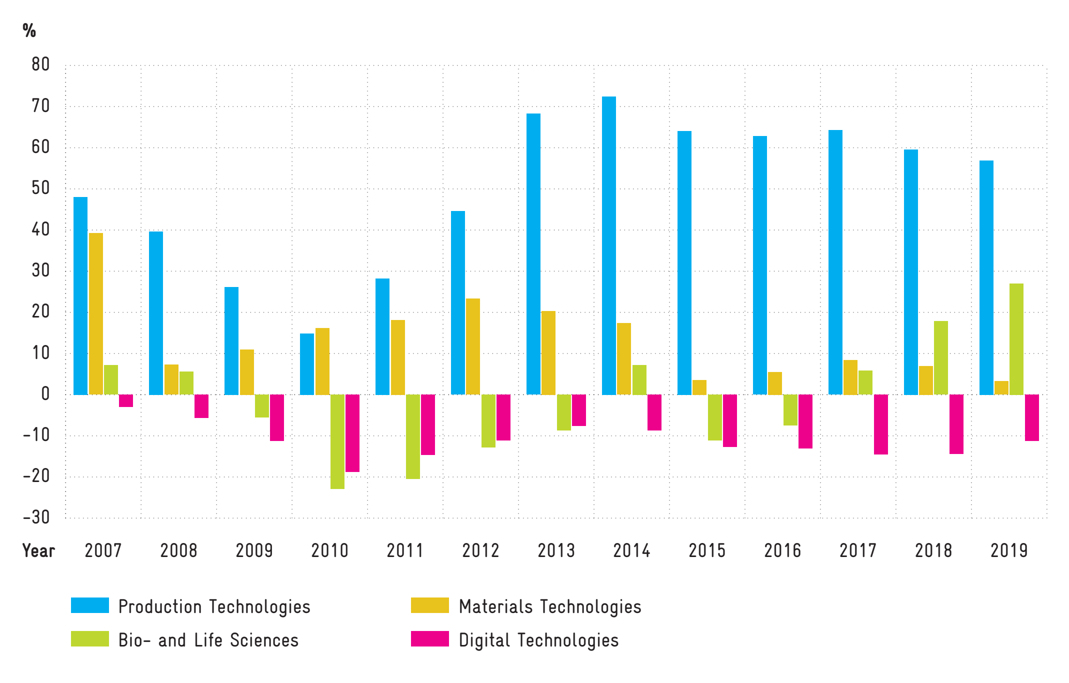

Source: Own representation based on Kroll et al. (2022).

enabling technology area of bio- and life sciences, the relative trade balance is at times negative and at times positive during the period under review but has been clearly positive since 2017. In the area of digital technologies, Germany has a negative relative trade balance over the entire period under review, i. e. it is a net importer.

Trade Specialization: Germany and EU 27 with Weaknesses

The trade specialization of an economy and its position in international comparison can be described using the revealed comparative advantage (RCA). Here, the RCA describes the export share of a key enabling technology in a country in relation to the share of this key enabling technology on the world market.[160] If the RCA is positive, the country has a comparative trade advantage in the respective key enabling technology. If, on the other hand, the RCA is negative, this indicates a comparative trade disadvantage.

Germany has both comparative trade advantages and disadvantages in the key enabling technology areas of production technologies, materials technologies and the technologies of the bio- and life sciences (see figure B 1-7). Germany's trade advantages lie in the individual technologies of photonics, advanced manufacturing, new materials and in the life sciences. Trade disadvantages for Germany can be seen in robotics, bioeconomy and nanotechnology, but above all in the entire area of digital technologies. The comparative disadvantages are particularly pronounced in the individual technologies of digital security, big data, microelectronics and artificial intelligence.

The EU 27 have similar comparative advantages and disadvantages as Germany. This applies in particular to the area of digital technologies, in which the EU 27 consistently display comparative disadvantages. In contrast, China has pronounced comparative trade advantages in all digital technologies, which are even surpassed by South Korea in microelectronics, digital security and digital mobility.

Fig. B 1-7 Mean value of revealed comparative advantage in individual technologies for selected countries and regions 2016–2018 in percent

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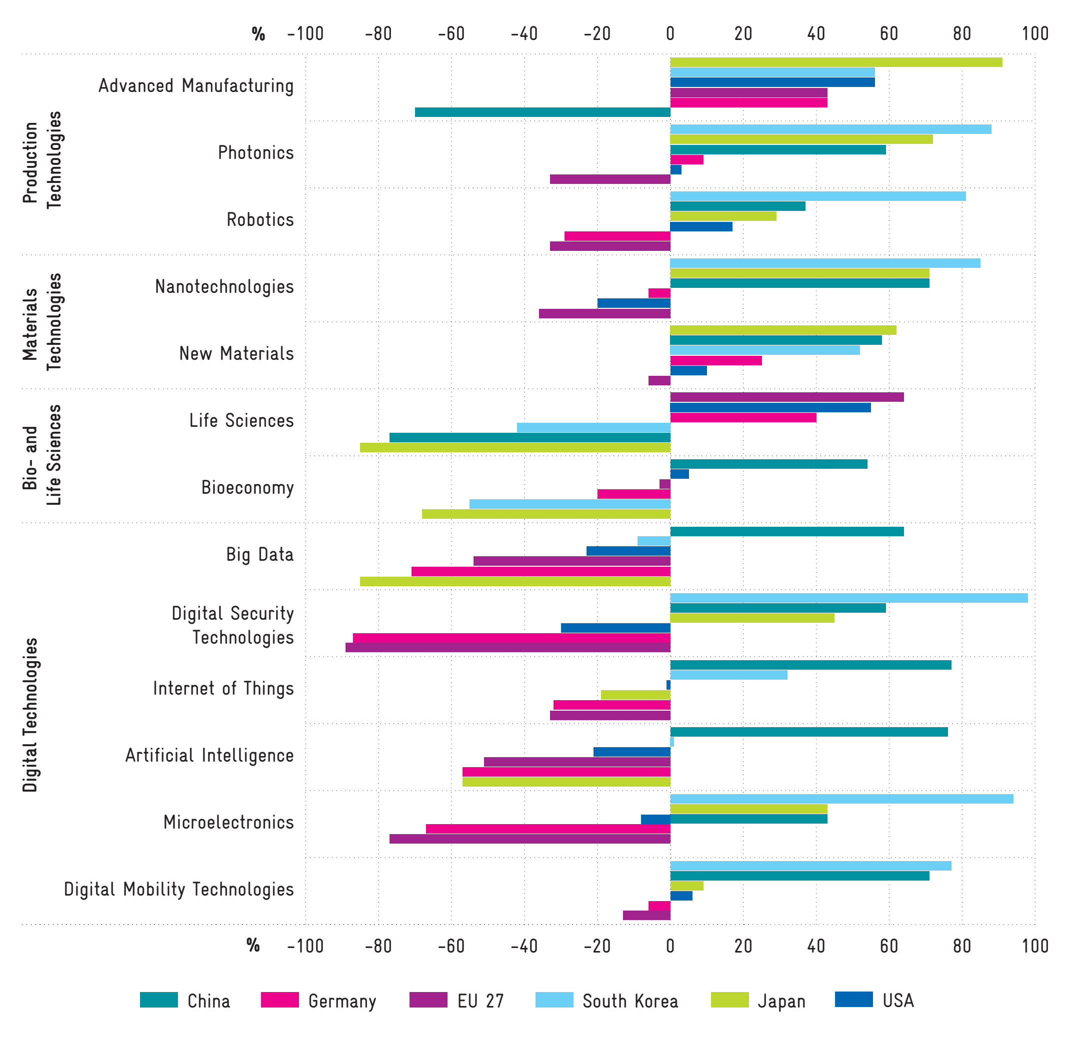

A positive value indicates a comparative advantage, a negative value a comparative disadvantage.
Source: Own representation based on Kroll et al. (2022).

Most Important Countries of Origin of German Imports: China Dominant

One indicator of Germany's direct dependence on another country for a key enabling technology is the import share. This indicates what percentage of German imports of a key enabling technology derives from another country. A high value indicates a possible dependence.[161]

The analysis of the import shares for the years 2015 to 2019 shows that China leads the ranking of the most important countries of origin of German imports in nine of the 13 individual technologies. The high importance of Chinese imports is particularly evident in the area of digital technologies, as China is the most important country of origin in five out of six individual technologies. The European countries play a subordinate role as countries of origin of German imports compared to China except in the individual technology of life sciences.[162]

Standard Setting: Digital Technologies Neglected in Germany

Global and European technological standards are a key factor for the development and dissemination of key enabling technologies. Representatives from science and industry discuss and agree on these standards in international standardization committees.

Unlike Germany and many Western countries, China does not leave the setting of standards to the individual responsibility of the companies and organizations concerned but relies on centralized and controlled state action.[163] China has massively expanded its involvement in standardization organizations in recent years. By contrast, German companies and organizations do not seem to succeed in making a significant contribution to forums for negotiating future standards in the particularly dynamic key enabling technology area of digital technologies.[164]

Cooperation with Asian Countries Insufficient

An analysis of Germany's scientific and technological cooperation patterns with other countries shows that they still reflect the structures of the 1980s and 1990s. While German science organizations and companies have close cooperation structures with European and North American partner countries, which are reflected in pronounced co-publication and co-patenting activities, comparable links have not been established with the technologically leading companies and organizations in Asian countries.[165]

In the case of Japan and South Korea, this shortcoming could be related to the traditionally low propensity of the corporate sectors there to cooperate internationally.[166] In the case of China, the reason for this can also be seen in the increasing state control and supervision of the science and business sectors, as well as in the unequal conditions of competition and cooperation (unlevel playing field) for German and Chinese stakeholders.[167] In addition, the growing systemic competitive relationship between the Western world and China contributes to German organizations perceiving long-term cooperation with China as risky.[168] There is a risk that the availability of key enabling technologies and related knowledge will be increasingly limited as a result.

B 1-3 Promotion of Key Enabling Technologies as a Political Task

The danger of an economy falling behind in key enabling technologies in international competition and thus having to accept losses in prosperity and welfare development as well as in its self-reliance leads to the topics of key enabling technologies and technological sovereignty being placed high on the political agenda in many countries.

Measures for Safeguarding Technological Sovereignty

From the conceptual considerations in section B 1-1, political approaches can be derived that can in principle be addressed with the following presented R&I policy measures. These measures are used in different combinations and intensities in political practice.

With regard to the mastery of key enabling technologies, measures to build up knowledge and skills in the field of key enabling technologies are of help in the medium and long term. Here, the promotion of science and research, vocational and continuing education and training as well as academic education should be considered. In addition, knowledge and technology transfer to the economy and society as well as key enabling technology-specific innovation activities should be promoted.

Industrial and foreign trade policy measures can also ensure in the short term that the generation, further development and above all the production of key enabling technologies remain in an economy. Subsidies for selected key enabling technologies, protectionist measures for the import of key enabling technologies and measures to promote exports can help to reduce the problem of limited availability and insufficient mastery of a key enabling technology. Measures of this kind can have the effect that key enabling technologies are produced and further developed domestically (increasing availability) and that learning effects can be generated and used in the process (improving mastery).

The use of industrial policy measures should be limited in time and should take place at an early stage, when a key enabling technology is still young and the exploitation of its technological and economic potential is still in its infancy. The risk of losing touch with international developments is particularly great especially in the early phase of a new key enabling technology. This is where the argument of infant industry protection or infant technology protection comes into play. It states that new industries or technologies should be protected from international competition until they are mature and strong enough to face this competition.

Industrial policy support can also be designed in such a way that R&I activities are not supported across the entire breadth of a key enabling technology, but only in selected sub-areas of this technology. This would amount to a structure of intra-technological specialization in which several national economies are leaders in a given key enabling technology, but each in different sub-areas or niches. Through international trade, these economies would complement each other.

In this way, unequal power relations in conflict situations could be balanced. Should a trading partner try to use its position of strength in a way that limits the technological sovereignty of other economies, these in turn could use existing strengths in (complementary) technological sub-areas as a means of counter-pressure.

Germany: Technological Sovereignty Through Own Competences

The debate on the control and availability of key enabling technologies to safeguard technological sovereignty is comparatively young in Germany. The COVID-19 pandemic and the disruption it caused to value chains has drawn increased attention to the limited availability of technological components. Against this background, there is now also increased discussion in this country about how independent Germany and the EU need to be with regard to certain technologies.[169] The establishment of a Council for Technological Sovereignty in September 2021 by the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) illustrates the increased importance of the topic in the political arena.[170]

According to the BMBF's ideas, technological sovereignty should be secured primarily by building up and strengthening Germany's own scientific and technological competencies.[171] Reinforcing the German R&I system in cooperation with European partners should ensure that science and industry are able to 'shape the development and application of key enabling technologies internationally on an equal footing and in line with our values.'[172]

Only recently have industrial policy interventions in the market mechanism been brought into the discussion. For example, in its impulse paper on technological sovereignty, the BMBF formulates that it may be necessary to 'develop key enabling technologies and technology-based innovations in Europe independently and to build up own production capacities for them if this is necessary to maintain the state's ability to act or to avoid unilateral dependencies'.[173] In doing so, the BMBF is moving in the direction that the then Federal Ministry for Economic Affairs and Energy (BMWi) had already taken earlier with its Industrial Strategy 2030 and the tightening of investment control.[174, 175]

To boost scientific and technological competencies, the Federal Government has formulated and pursued various strategies in recent years to promote technologies, including key enabling technologies.[176] The High-Tech Strategy 2025 also focuses on promoting key enabling technologies in particular by building scientific and technological capabilities.[177] Beyond its own national initiatives, the Federal Government is also active at the EU level to promote selected key enabling technologies and thus to secure Germany's and Europe's technological sovereignty in the sense of maintaining competencies.[178]

European Union: Technological Sovereignty Through Support

The promotion of key enabling technologies (KETs) in industrial policy was already considered by the EU in 2009.[179] Initially, the focus was on strengthening industrial manufacturing, and only then was the target dimension of technological sovereignty added.[180] Prominent examples of the promotion of key enabling technologies and the growing importance of technological sovereignty within the European funding portfolio are the European Partnership Initiatives[181] and the Important Projects of Common European Interest (IPCEI).[182] So far, three IPCEI initiatives have been launched, for the promotion of microelectronics, for the development and production of battery cells and for the production of hydrogen.[183] Further projects are planned.

The European Industrial Strategy, presented in 2020 and renewed just one year later, aims, among other things, to strengthen Europe's open strategic autonomy[184] and to create the conditions for investment in key enabling technologies.[185] As part of this update, the EU Commission also presented an instrument to monitor the EU's strategic dependence on non-European products and technologies[186] as well as a revision of its competition law to combat the competition-distorting effects of foreign subsidies on the European internal market.[187] In addition, the Commission announced a European standardization strategy to safeguard European interests in standardization inside and outside the EU.[188] The measures make it clear that both the question of mastery and the question of availability of key enabling technologies are of increasing importance for the EU.

China: Technological Sovereignty Through Open Industrial Policy

The Chinese understanding of technological sovereignty is strongly shaped by the goal of mastery and availability. With its industrial policy, China not only wants to be the world leader in a large number of technologies, including key enabling technologies, but also to dominate entire value chains and successively replace foreign technology providers with domestic ones.[189]

In the long term, the Chinese state is promoting the development of numerous key enabling technologies with massive investments[190] and is pushing the involvement of Chinese organizations in international standardization bodies.[191] Moreover, the state not only assumes a central guiding, framing and supporting function. As a quasi-entrepreneur and provider of capital, it is itself significantly involved in the implementation of its own technical-economic specifications.[192]

In addition, the state pushes industrial capacity and competence building at home and restricts access to domestic markets for foreign competitors. Examples include the Cybersecurity Act of 2017 and the Export Control Act of 2020.[193]

USA Technological Sovereignty Through Covert Industrial Policy

For the USA, its claim to global political leadership is closely linked to a claim to technological leadership. To assert a leading position in as many key enabling technologies as possible, the USA, in contrast to China, pursues a rather covert industrial policy.[194] To this end, the development and application of selected key enabling technologies is supported in the long term by formulating favourable framework conditions and targeted funding programmes. Examples of these support programmes are the national initiatives on AI, nanotechnology and robotics as well as on advanced manufacturing.[195]

Moreover, especially since the global financial and economic crisis of 2008/09, state intervention and approaches of explicit industrial policy have become increasingly popular in US-American industrial policy.[196] Also under the Biden administration, an industrial and trade policy can be observed that regulates China's access to the US-American market and restricts exports and international technology transfer.[197] The USA thus pursues the approach of not only promoting the mastery of key enabling technologies, but also securing its dominant position in individual technologies by restricting the availability of key enabling technologies to competing states.

B 1-4 Recommendations for Action

In terms of publications, patents and foreign trade, Germany shows strengths in the key enabling technology areas of production technologies as well as bio- and life sciences in an international comparison. In the area of digital technologies, on the other hand, Germany, like the EU 27, shows clear weaknesses. This means that they are not only losing touch in a technology area that is becoming more and more important economically but are also jeopardizing their existing strengths in other key enabling technology areas such as production technologies and the bio- and life sciences, which are increasingly being penetrated by digital technologies. This problem is exacerbated by the fact that Germany is dependent on imports from China, especially in digital technologies.

Establishing a Monitoring and Advisory Body for Key Enabling Technologies

Unlike in China and the USA, the strategic promotion of key enabling technologies in Germany is still in its infancy. The focus of German funding efforts is on knowledge building. Strategic monitoring of key enabling technologies and concerted capacity building for the development and use of key enabling technologies in the pre-market and market sector have hardly taken place so far. The Commission of Experts therefore recommends the following measures:

— Key enabling technologies and derived key enabling technology portfolios must be defined using clear and operationalizable criteria to ensure that their selection is not determined by assertive individual interests.

— Key enabling technologies should be systematically kept under review through continuous foresight analyses and monitoring processes. To this end, the Federal Government should set up a monitoring unit, preferably with a European composition, consisting of several independent research institutions. The aim of these monitoring processes must be to record current, emerging and potential key enabling technologies and to assess them in terms of their technological, economic and societal potential.

— In addition, the Federal Government should establish an independent strategic advisory committee for key enabling technologies. This committee has the task of evaluating the information from the European monitoring unit and compiling it into a continuously updated key enabling technology portfolio. In addition, the committee should formulate recommendations for action on how to deal with selected key enabling technologies for the Federal Government at regular intervals.

Thinking About Support in European Terms and Shaping Market Interventions Catalytically

The EU 27 and Germany are in danger of losing the ability to master important digital key enabling technologies. The availability of these technologies on international markets is also at risk. This can lead to massive restrictions on technological sovereignty not only in the area of digital technologies, but also in the other key enabling technology areas whose development increasingly depends on and is driven by digital technologies.

— In key enabling technology areas where technological leaps are emerging, funding should be provided not only for contributions to basic research, but also for application-oriented pilot projects. It is important to initiate the accompanying development of corresponding competences in academic education as well as in vocational and continuing education and training at an early stage.

— As a reaction to changes in the world trade system and the ideal of a level playing field, which is coming under increasing pressure, the Federal Government should not only focus its promotion of key enabling technologies on the pre-market sector. To promote potential key enabling technologies (infant technologies), subsidising interventions can also be made in the market, provided they have a catalytic character, i. e. they have a knock-on effect and are then withdrawn again.

— To reinforce key enabling technologies and their own technological sovereignty, Germany and the EU must take stronger joint action to achieve a critical mass of capacities and activities.

— Germany should become more involved in existing European programmes such as the IPCEI initiatives and set priorities through co-financing and content-related contributions.

— In view of the great importance of digital technologies, especially for the development of other key enabling technologies, solutions for new application contexts at the intersection of digital and other key enabling technologies should be specifically promoted.

Increasing Engagement in Standardization Committees

German involvement in the standardization committees, especially for digital technologies, is low.

— Appropriate incentives to participate in the international standardization committees should be set. The costs incurred by companies in connection with standardization projects could be subsidised through the research allowance.

— Companies and scientific institutions should be made more aware of the topic of standardization.

Improving Framework Conditions for Cooperation with Asian Partners

The scientific and technological cooperation of German organizations has so far focused mainly on European and US partners; suitable framework conditions can support the opportunities for cooperation with East and Southeast Asian countries, which are particularly strong in digital technologies.

— The Federal Government should improve the framework conditions for cooperation with Asian partners, especially in digital technologies. To this end, a competence centre, as already proposed by the Commission of Experts in 2020, should systematically collect and evaluate information on experiences and problems in cooperation projects and make it available to research institutions and companies. Furthermore, a level playing field with equal competitive conditions and prerequisites for action must be established for all stakeholders involved.

B 2 Motorized Private Transport on the Road to Sustainability

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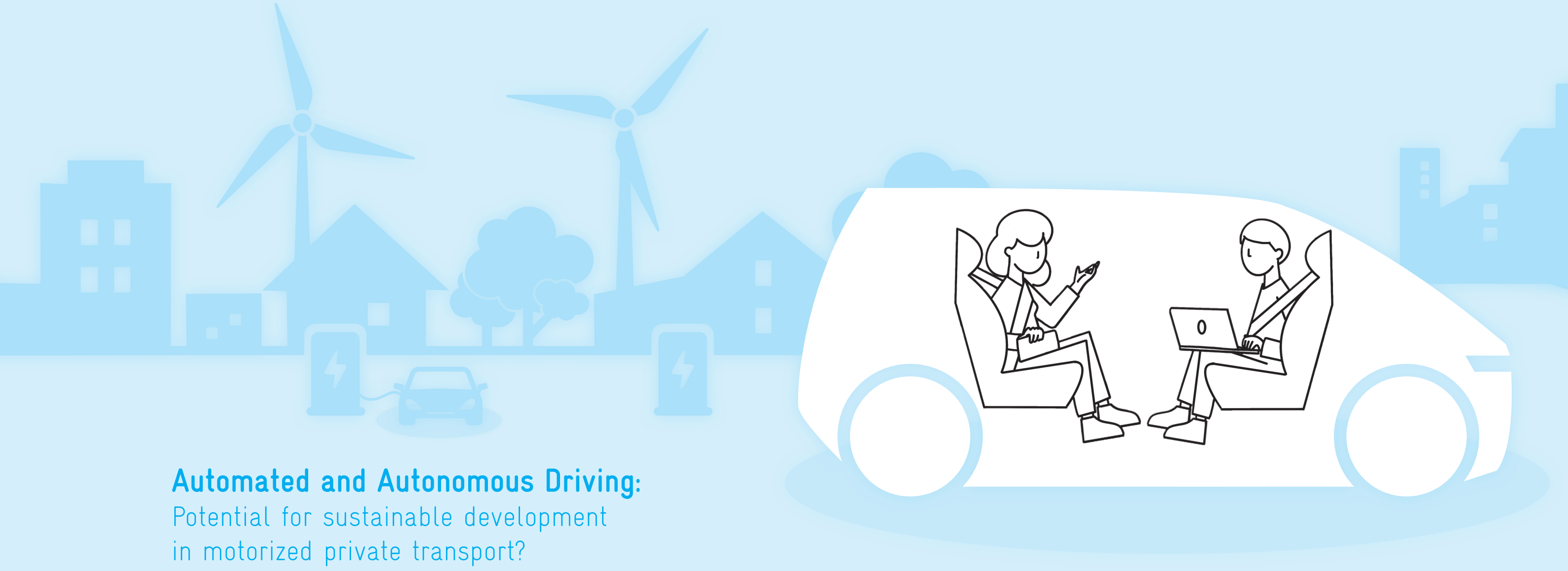
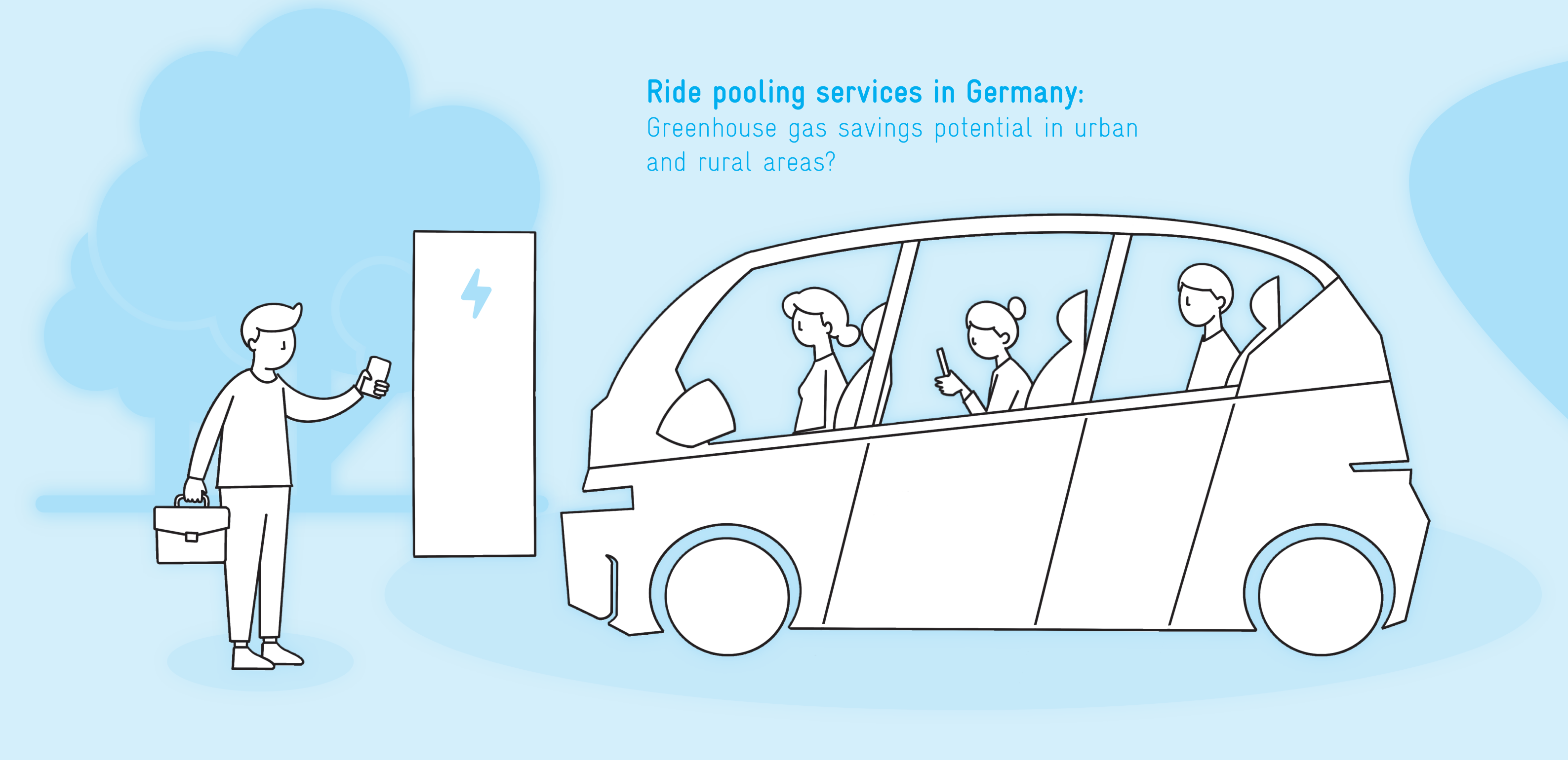
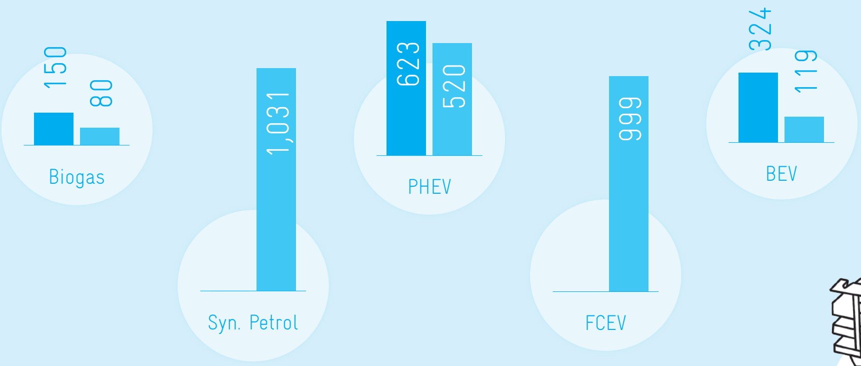
German policy is faced with the major challenge of having to bring emissions from the transport sector to zero as early as 2045. Private motorized transport is a major source of greenhouse gas emissions. A reduction in these emissions can be achieved at vehicle level through the use of new drive systems and alternative fuels. The battery-powered passenger car is proving to be the most ecologically and economically advantageous alternative. In addition, developments in digitalization and autonomous driving open up opportunities for innovative mobility services in order to contribute to the reduction of emissions by bundling transport, especially in the form of car sharing and on-demand transport.



Automated and Autonomous Driving:
Potential for sustainable development in motorized private transport?

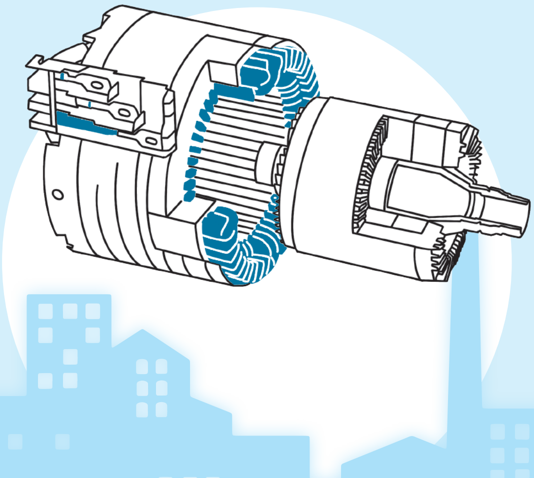


Ride pooling services in Germany:
Greenhouse gas savings potential in urban and rural areas?



GHG reduction costs of alternative drive systems and fuels compared to a conventional petrol engine in euros per tonne of CO_2 equivalent

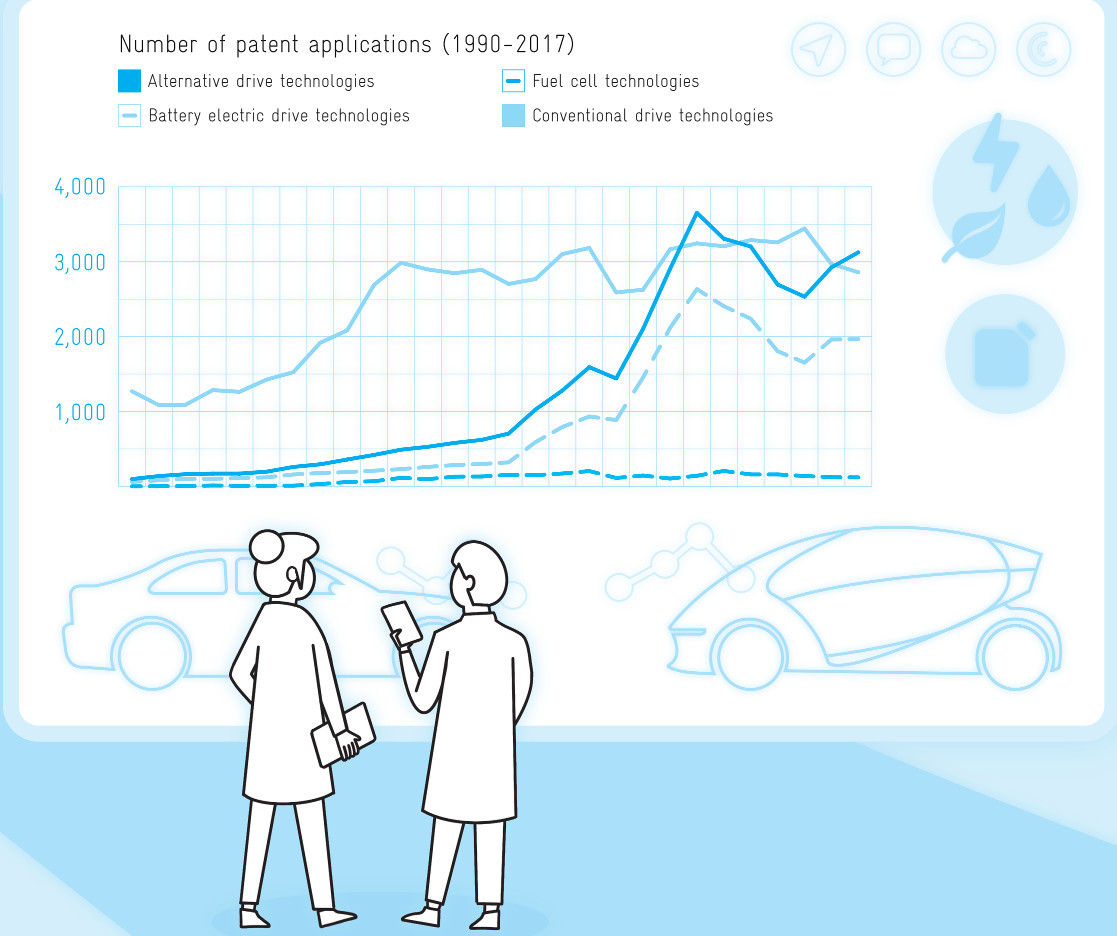
2020 2030



Life cycle assessment and economic analysis of conventional and alternative drive systems:
Are alternative drive systems the right way to go?

Innovation activity in the area of drive systems and automated driving: Where does Germany stand in international comparison?

Number of patent applications (1990-2017)



B 2 Motorized Private Transport on the Road to Sustainability

German policy is faced with the major challenge of having to bring emissions from the transport sector to zero as early as 2045. Motorized private transport (MPT) is a major source of greenhouse gas emissions.[198] A reduction in emissions from MPT can be achieved in various ways: by reducing the total distance travelled, by using lower-emission vehicles and by changing the choice of transport modes. On the one hand, this chapter focuses on emission reductions at the vehicle level through use of new drive systems and alternative fuels. On the other hand, it examines the extent to which innovations through digitalization and automated driving can contribute to the bundling of transport, especially in the form of car sharing and on-demand transport.

Purely battery-powered electric cars are proving to be the most economically advantageous option for reducing emissions at the vehicle level. However, their purchase and operation are currently not sufficiently attractive without accompanying policy measures. To accelerate the spread of purely battery-powered electric cars, a higher CO_2 price and a well-developed charging infrastructure with competitive and transparent prices are needed.

With regard to new drive technologies, the German automotive industry is well positioned in international comparison. Together with Japan, it leads the world in terms of both patent applications and sales figures. In the area of automated driving, the USA, Germany and Japan are ahead, with the USA leading by far in the sub-area of autonomous driving.

Legal adjustments are still needed for the widespread use of autonomous vehicles to bundle transport. In this way, better offers and innovative business models can develop that make the switch from private transport to bundled forms of transport more attractive.

B 2-1 Life Cycle Assessments of Alternative Drives

The discussion about low-emission drive systems has triggered various technological developments. For a meaningful assessment of the ecological reduction potentials, especially of greenhouse gases (GHG), of these new drive systems, the Commission of Experts commissioned a study. In this study, the total GHG emissions, the emissions of other air pollutants and the use of critical raw materials during the production, use and disposal phases are balanced for vehicles in the compact class.[199] The key assumptions of this balance are shown in box B 2-2. The following drive systems are compared: conventional internal combustion engine vehicles (ICEV), powered by petrol, diesel, biogas or synthetic fuels,[200] battery electric vehicles (BEV), plug-in hybrid vehicles (PHEV) and fuel cell electric vehicles (FCEV) (see box B 2-1).

Key determinants of emissions and the relative advantage of alternative drive systems are the battery technology used, the size of the batteries installed, the option of replacement batteries, the total mileage and the electricity mix used in power generation.

Comparing state-of-the-art vehicles purchased in 2020, BEVs, FCEVs and PHEVs generate significantly more GHG emissions during vehicle production and disposal than conventional petrol and diesel vehicles (see figure B 2-3). GHG emissions in

Box B 2-1 Conventional and Alternative Drives

ICEV Petrol/Diesel: Vehicles with a conventional internal combustion engine drive develop kinetic energy from the combustion of conventional fuels such as petrol or diesel. Biofuels or synthetic fuels such as methanol or biodiesel can be added to these fuels.[201]

ICEV Gas: In gas drives, natural gas or biogas is compressed and carried in a special tank in the vehicle. There are vehicles with a pure gas drive as well as vehicles that can use both petrol and natural gas.

BEV: Battery electric vehicles convert electrical energy into kinetic energy in an electric motor. The motor is supplied with energy from a battery that is charged from the power grid and from recirculated braking energy.

HEV: In hybrid electric vehicles, an electric drive supports the combustion engine to save fuel. In the so-called full hybrid,[202] purely electric driving is possible at low speeds. The battery is charged exclusively by the engine and the recovery of braking energy.[203]

PHEV: Unlike a full hybrid electric vehicle, a plug-in hybrid electric vehicle has a charging device to charge the battery directly from the power grid.[204]

FCEV: In fuel cell electric vehicles, the energy to operate an electric motor is generated from the reaction of hydrogen and oxygen in a fuel cell. A battery, which is small compared to BEVs, is used to balance and temporarily store the energy produced by the fuel cell as well as recovered braking energy.[205]

manufacturing are only slightly lower in 2030 than in 2020 across all drive systems.[206] For petrol- and diesel-powered vehicles, emissions in vehicle manufacturing are higher in 2030 than in 2020 due to the assumed switch to hybrid drives. For BEVs, emissions decrease by 2030 due to improved manufacturing processes. However, this reduction is largely offset by increasing battery capacities. FCEVs have the highest emissions in manufacturing in 2020, but also in 2030 despite considerable technological progress.

Over the entire lifetime, vehicles powered by biogas cause the lowest GHG emissions (see figure B 2-4).[208] However, biogas is not a sufficiently scalable option.[209] Among the new technologies, BEVs already have the lowest GHG emissions in 2020. They are only about half as high as with a conventional petrol engine.[210] FCEVs do not yet have any advantages over conventional drives in 2020. This changes in 2030, however, because the high energy demand for producing the hydrogen required in use will then be covered by a lower-emission electricity mix. In comparison, however, FCEVs still perform worse than BEVs. A similar picture emerges for ICEVs powered by synthetic fuels. For PHEVs, GHG emissions depend crucially on driving and charging behaviour. If these vehicles are driven like petrol vehicles, emissions actually increase compared to petrol vehicles due to the higher weight and more complex technology.[211, 212]

In addition to greenhouse gases, transport also emits other pollutants that have a significant impact on the environment, primarily nitrogen oxides (NO_X)[213] and particulate matter.[214] These are now dominated by emissions from electricity and vehicle production, due to the constant tightening of exhaust gas limits. Conventional vehicles have the lowest NO_X and particulate matter emissions over their entire service life. While NO_X emissions from BEVs are slightly higher and particulate matter emissions are significantly higher than those from conventional vehicles, FCEVs and synthetic fuel vehicles perform worst for both pollutants.[215]

Despite the increased NO_X emissions from BEVs, the shift of these emissions from the exhaust pipe to the stacks of power plants and manufacturing facilities improves air quality in urban areas close to traffic. This is an aspect that has a positive impact on the evaluation of electrically powered vehicles.[216]

An assessment of the sustainability of alternative drive systems must also take into account the use of critical raw materials, the extraction of which

Box B 2-2 Assumptions on Vehicles, Batteries and Electricity Mix

The study looks at the environmental balance and the economic efficiency of a compact class vehicle (e.g. Ford Focus, VW Golf, Toyota Corolla) purchased in 2020 or 2030 and driven for 15 years. Realistic driving behaviour is assumed as far as possible. For PHEVs, a charging behaviour is assumed that enables the use of the electric drive component. In contrast, empirical results from Plötz et al. (2020) show a significantly lower use of the electric drive in PHEVs. In 2020, the vehicle batteries will still be produced overseas (China, South Korea, Japan, USA). For 2030, the study assumes cell production in Europe and thus a European electricity mix in battery production. The modelled vehicle uses nickel-manganese-cobalt batteries, in which technological progress will reduce the proportion of cobalt by 2030 and at the same time achieve a higher energy density.

Download Data

Assumptions on Vehicle and Battery	2020	2030
Mileage over vehicle lifetime	187,500 km	187,500 km
Vehicle lifetime	15 years	15 years
Real fuel/energy consumption per 100 kilometres		
— ICEV Petrol	7.1 l	5.6 l
— ICEV Diesel	5.9 l	5.5 l
— ICEV Gas	4.7 kg	3.8 kg
— BEV	18.8 kWh	16.9 kWh
— PHEV	3.4 l + 11 kWh	1.8 l + 13.2 kWh
— FCEV	1 kg	0.8 kg
Average capacity of the vehicle battery for BEV (vehicle range)	55 kWh (ca. 290 km)	69 kWh (ca. 410 km)
One battery per vehicle life is assumed.		
Energy density per kilogram	150 Wh	200 Wh

Assumptions on Energy Mix	2020	2030
GHG emissions from electricity generation per kWh	470 g	146 g

The assumed development of the electricity mix follows the Greenhouse Gas Neutral Scenario of the former Federal Ministry for Economic Affairs and Energy (BMWi),[207] which assumes that GHG emissions in Germany will decrease by 65 percent from 1990 to 2030 and by 88 percent to 2040 by increasing the share of renewable energies.
For ICEV petrol and ICEV diesel, a switch to hybrid drives is assumed in 2030. HEVs are not considered separately in the study.

causes considerable external environmental costs in the producing countries. In battery production, cobalt and lithium are among the most important critical raw materials,[217] in fuel cells it is mainly elements of the platinum group, of which large quantities would be needed at the current state of the art.[218] Since the demand for critical raw materials will increase with rising demand for vehicles with alternative drives, despite expected technological progress and recycling, it is advisable to push ahead with the development of batteries that largely dispense with such raw materials, e.g. sodium-ion batteries.[219, 220, 221]

Resource Consumption of Different Drive Systems in Comparison

Vehicles with alternative drives are currently still significantly more expensive to purchase than conventional vehicles. From an economic perspective, the different drive systems can be compared with each other based on the so-called Total Cost of Ownership (TCO). The TCO evaluates the direct resource consumption in the production, use and disposal of a vehicle over its entire service life at market prices.[222]

Figure B 2-5 shows the results of TCO calculations carried out by Fraunhofer ISI on behalf of the Commission of Experts. According to these, the costs of

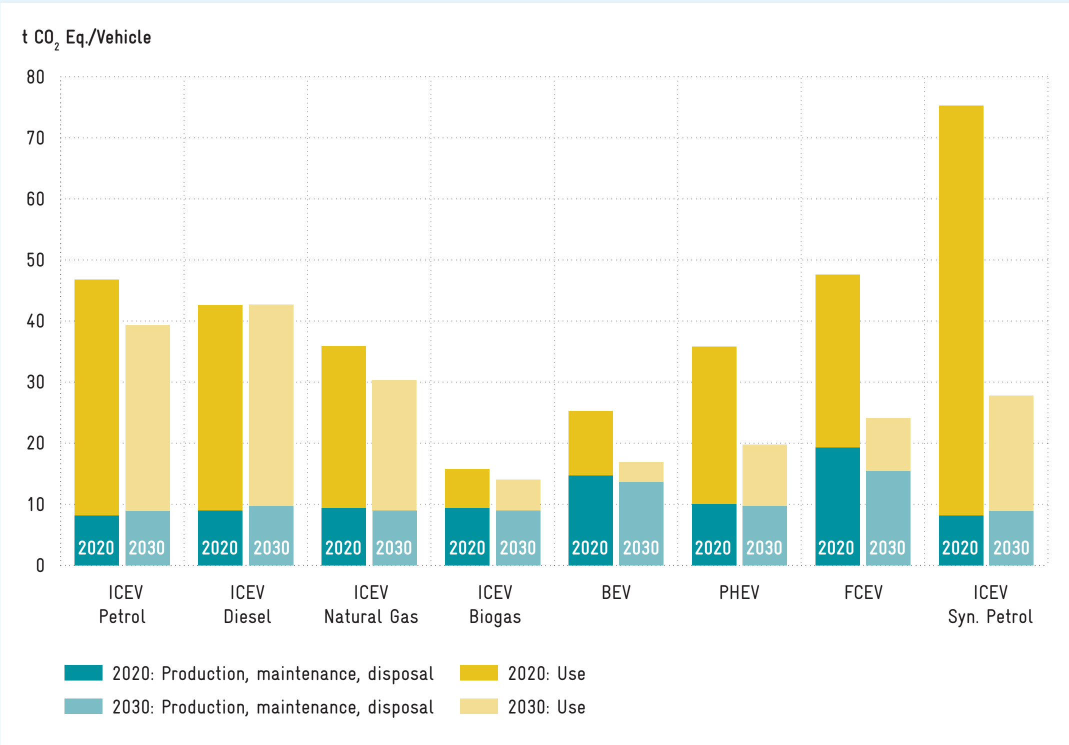
Fig. B 2-3 GHG emissions from vehicle production and disposal for a compact vehicle purchased in 2020/2030 in tonnes of CO_2 equivalent

[Download Data](#)

Source: Own representation based on Wietschel et al. (2022).

Fig. B 2-4 GHG emissions over the vehicle lifetime for a compact vehicle purchased in 2020/2030 in tonnes of CO_2 equivalent

[Download Data](#)



Source: Own representation based on Wietschel et al. (2022).

Fig. B 2-5 TCO results for a compact vehicle purchased in 2020/2030 in euros

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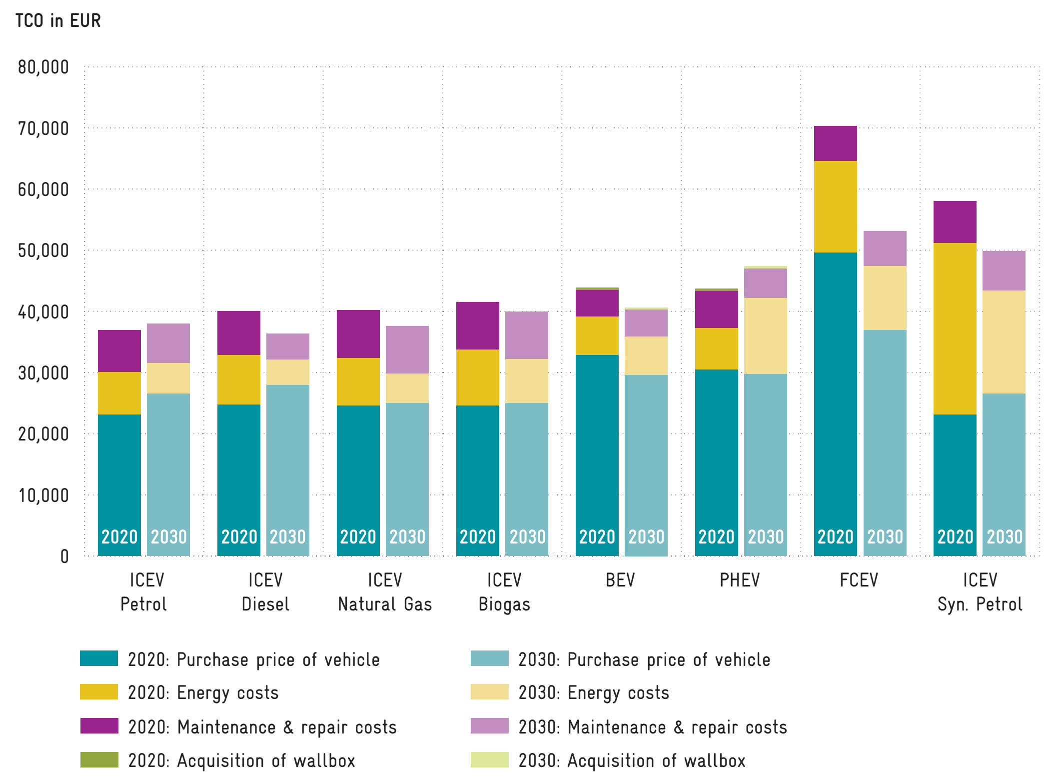

Purchase price of the vehicle including battery, if applicable.
Energy costs: Depending on the drive type, these include expenditure on petrol, diesel, gas, electricity and synthetic fuels consumed during vehicle use.
Maintenance and repair costs: During the use phase, costs are incurred for maintenance and repairs. These include all expenses for maintaining the vehicle in running condition that are not included in energy costs.
Acquisition of wallbox: This includes the cost of purchasing a charging station that allows PHEVs and BEVs to be charged via the in-house power connection.
All prices are to be understood as net prices.
Source: Own representation based on Wietschel et al. (2022).

direct resource consumption are lowest for conventional ICEVs in 2020 and 2030. The TCO of biogas are also relatively low. For BEVs, the TCO in 2020 is €7,000 higher than for conventional petrol vehicles. For FCEVs and ICEVs powered by synthetic fuels, the difference is €33,500 and €21,000, respectively. In 2030, the TCO for alternative drive vehicles, except for PHEVs, are a good deal lower than in 2020, but the resource consumption costs compared to conventional ICEVs are still higher.

The higher costs of BEVs are mainly due to the manufacturing costs of the batteries, while those for FCEVs and ICEVs powered by synthetic fuels are due to the high energy consumption for the production of hydrogen and synthetic fuels, respectively.[223]

Costs of Greenhouse Gas Reduction for BEVs Relatively Low

Using the differences in TCO and emissions per vehicle lifetime between a vehicle with an alternative drive system and a vehicle with a conventional drive system, it is possible to determine what it costs to save one tonne of CO_2 by changing drive systems. Figure B 2-6 shows these GHG reduction costs for 2020 and 2030. Here, a conventional petrol engine serves as a reference. The ICEV biogas drive, although difficult to scale, has the lowest GHG reduction costs in both years. For BEVs, the GHG abatement costs are slightly higher, for PHEVs significantly higher.[224] FCEVs and vehicles fuelled with synthetic fuels produce even higher GHG emis-

Fig. B 2-6 GHG reduction costs of alternative drive types and fuels compared to a conventional petrol engine 2020/2030 in euros per tonne of CO_2 equivalent

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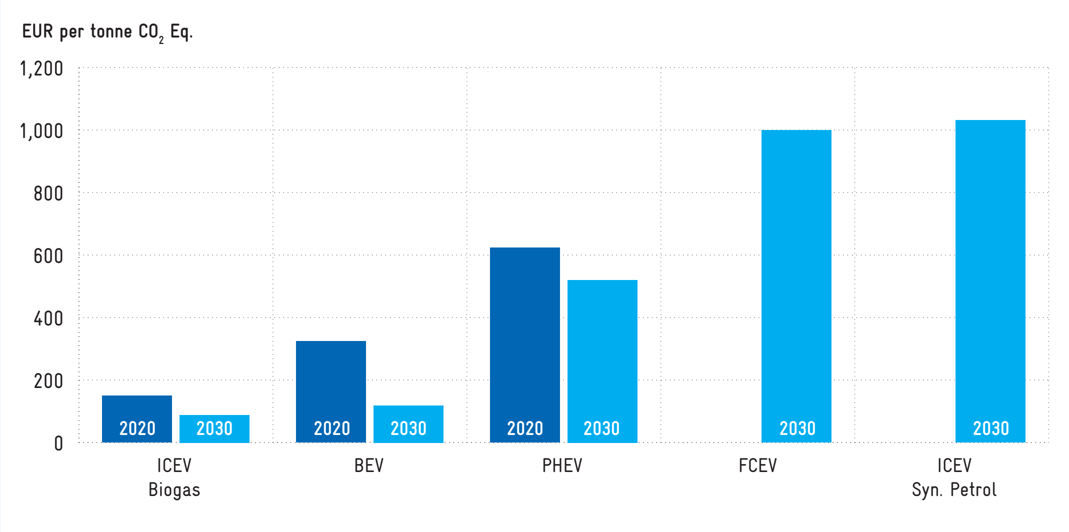

GHG reduction costs for FCEV and ICEV Syn. Petrol cannot be meaningfully stated in 2020 because these have even higher GHG emissions than a conventional petrol vehicle in 2020.
Source: Own representation based on Wietschel et al. (2022).

sions in 2020 than a conventional petrol engine, so that GHG abatement costs cannot be meaningfully stated. In 2030, they produce less GHG emissions than the reference drive, but their GHG reduction costs are by far the highest due to the high electricity demand.

The TCO does not take into account the external effects caused by the emission of GHG during the production and use of the various drive type vehicles. From an economic point of view, a change to an alternative drive system is advantageous if the external costs of the conventional drive per tonne of CO_2 are higher than the additional costs of the TCO determined above (see figure B 2-5) due to the change of drive. If the estimated value of the external CO_2 costs of €215 per tonne of CO2 equivalent calculated by the Federal Environment Agency (Umweltbundesamt, UBA) is taken as a basis, it becomes apparent that the additional costs of BEVs will exceed the external costs in 2020. In 2030, however, they are lower, so a switch from conventional petrol to BEVs will then be economically advantageous. In contrast, the other alternative drive systems, apart from the option of biogas, which cannot be scaled up, have a negative economic benefit-cost balance even in 2030.

Purchase Premiums Only Partially Effective

Currently, the Federal Government subsidizes the purchase of a BEV with up to €9,000 as well as a waiver of the vehicle tax over ten years with a total value of €2,000 to €3,000. With a saving of around 20 tonnes of CO_2 over the life cycle of a compact-class vehicle (see figure B 2-4), the reduction of one tonne thus costs the state between €550 and €600 per tonne of CO_2 equivalent, which clearly exceeds the actual abatement costs.

Nevertheless, there may be reasons to justify start-up funding. Vehicles with alternative drives are new products that can still expect cost degressions through learning and economies of scale, which the market only incompletely rewards.[225] In addition, promoting the purchase of vehicles with new drives can trigger direct and indirect network effects. Vehicles with new drives become more attractive for users the denser the charging infrastructure becomes. Conversely, the more vehicles with alternative drives are on the road, the more worthwhile it is to expand the network for private providers of charging stations. A purchase premium can trigger the resolution of this chicken-and-egg problem.

However, in contrast to a CO_2 price, the purchase premium does not have a steering effect with regard to emission-intensive driving modes. Furthermore, deadweight losses cannot be ruled out in some cases. For example, it can be observed that the existing purchase premium is disproportionately used for PHEVs and relatively heavy, fuel-intensive and thus emission-intensive vehicles.[226] Finally, flat-rate incentives such as the purchase premium typically generate rebound effects.[227]

Need for Change in Purchase Incentives

The question arises as to how the state can provide sufficient incentives for switching to an alternative drive system when buying a car. In addition to the TCO and the CO_2 price, the taxes on petrol and diesel as well as the vehicle tax are key factors in the decision to switch.[228] Because fuel consumption is associated with higher GHG emissions, the taxes on fuel for ICEVs ultimately have the same effect as a CO_2 price. For example, the current petrol tax corresponds to a price of about €220 per tonne of CO_2, i.e. it is approximately at the level of the environmental costs of GHG emissions of €215 per tonne determined by the UBA.[229] Such a price will only be a sufficiently high incentive from 2030 onwards. As shown above, the cost disadvantages per tonne of CO_2 saved when purchasing a passenger car with an alternative drive instead of a conventional petrol car are currently still consistently greater. This is why additional incentives, such as a purchase premium, are needed to steer the purchase decision in the direction of more sustainable drive systems.

Besides a purchase premium, there are other options to achieve this goal. One alternative, envisaged in the coalition agreement, is to differentiate the vehicle tax according to the drive system so that it also takes into account the emission of CO_2 and other pollutants. The difference between the vehicle tax rates for ICEVs and those for alternative drive systems would then have to be sufficiently large to make a switch worthwhile. Such an instrument would then have a similar effect to a purchase premium.

Another alternative is to directly price the external effects associated with use and the kilometres travelled instead of a flat-rate tax on vehicle ownership, as is the case with vehicle tax. In particular, an increase in fuel taxes[230] and a comprehensive road toll system could have corresponding steering effects on vehicle use. Vehicle taxes would be eliminated altogether.

Price Transparency and Expansion of Charging Infrastructure Necessary

To promote indirect network effects, the improvement of the charging infrastructure would be the more effective lever, since on the one hand, unlike the purchase premium, it directly benefits many users[231] and, on the other hand, the purchase premium, which is very expensive for the state, can be better replaced by purchase incentives via CO_2 pricing. In addition to an expansion of the stock of fast charging stations, for which around €2 billion have already been made available on the basis of the Fast Charging Act (Schnellladegesetz),[232] rules for transparent pricing at charging stations as well as technological compatibility are necessary in order to generate low prices for charging electric cars and other alternative drive systems through competition. Currently, however, the market for charging electric cars is characterized by fragmentation with confusing technological interfaces and different payment systems, which makes it difficult to compare prices and find cheap charging stations.[233]

Since FCEVs are neither ecologically efficient nor economical in the foreseeable future, there is no need to further expand the still thin hydrogen filling station network[234] for MPT at present. In addition, research is working on the development of a new generation of hydrogen storage systems, the so-called liquid organic hydrogen carrier technology,[235] which allow hydrogen to be stored and transported with the help of liquid carrier media. This would allow the existing logistics of the mineral oil industry to be converted with relatively little effort for continued use.

B 2-2 Patent Activities and Sales in the Field of Alternative Drives

In the following, patent activities and market shares in the field of alternative drive technologies are examined globally and in comparison with other countries in order to describe Germany's respective position in international competition. The basis for this is a study commissioned by the Commission of Experts on relevant transnational patent applications in the period from 1990 to 2017[236] and on passenger car sales figures by drive system in the period from 2010 to 2020.[237]

Patent Activities in the Field of Alternative Drives Growing Sharply Worldwide

Worldwide, the number of transnational patent applications in the field of alternative drives has risen sharply since 2004. Since 2011, it has been at a similar level to the number of patent applications in the field of conventional drives (see figure B 2-7).[238] The increase was mainly driven by patent applications in the field of battery electric drives.

Germany Catches Up in Patents on Alternative Drives

An international comparison of transnational patent applications in the field of alternative drives shows that the strong increase in the years 2004 to 2010 can be traced back primarily to Japan. Since then, however, the transnational patent applications coming from there have been in sharp decline.[239] In contrast, positive momentum has been recorded for Germany and, at a lower level, also for China[240] and the USA, especially since 2014 (see figure B 2-8). In 2017, Germany was almost on a par with Japan with 758 transnational patent applications in the field of alternative drive systems – ahead of the USA and China with close to 400 patent applications each.

Normalized relative patent shares (RPS) are a measure of the specialization of countries in a certain patent area.[241] Figure B 2-9 shows the normalized RPS of alternative drive technologies. A positive value indicates specialization in this area. The development of the RPS from 2005 to 2017 shows increasing specialization in these technologies for Germany and especially China. For the USA and Japan, the development is in the opposite direction.

Fig. B 2-7 Number of transnational patent applications in the fields of conventional and alternative drive technologies 1990–2017

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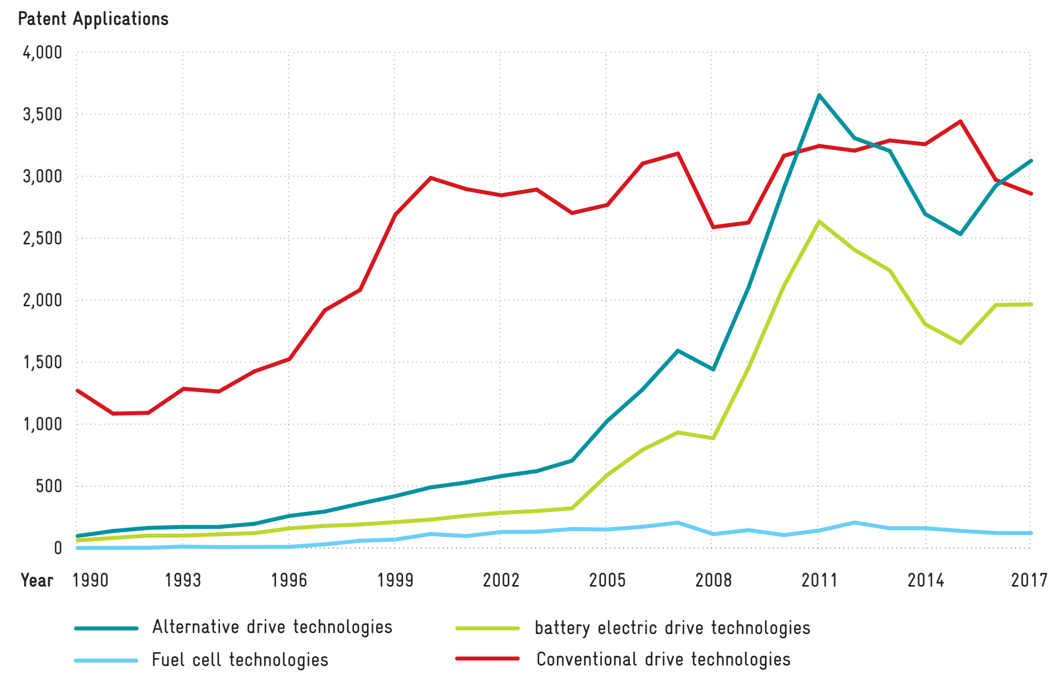

In addition to patent applications for battery electric drives and fuel cells, alternative drive technologies also include applications in the areas of power electronics and charging systems, which are not shown individually here.
Source: PATSTAT. Own representation based on Sievers and Grimm (2022).

Fig. B 2-8 Number of transnational patent applications in the field of alternative drive technologies in selected countries 1990–2017

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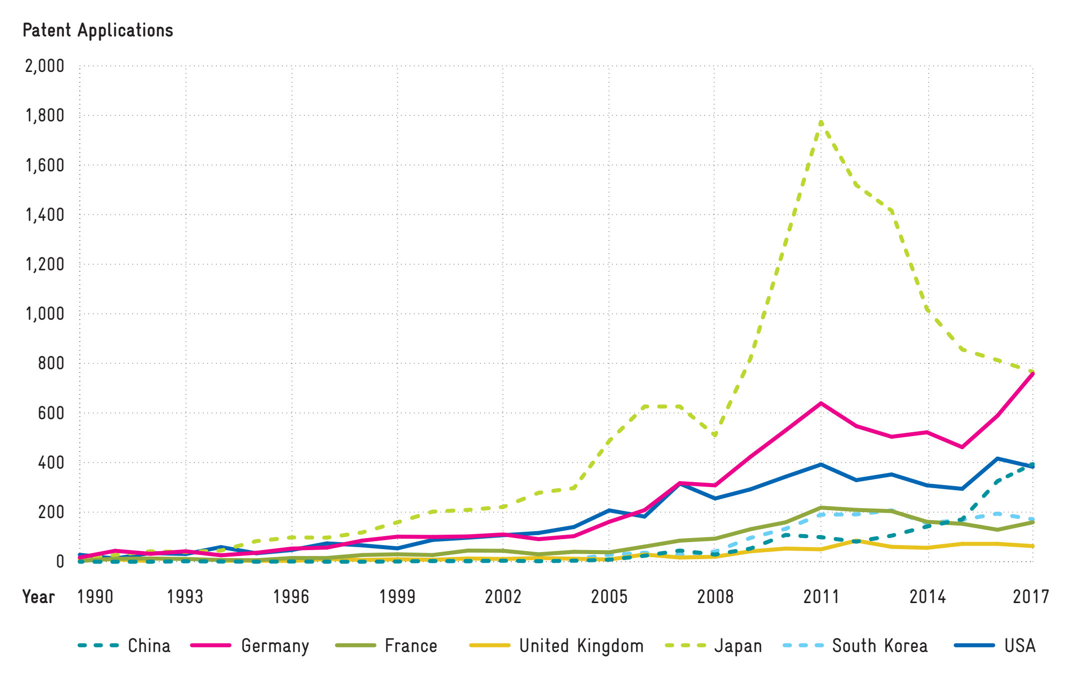

Source: PATSTAT. Own representation based on Sievers and Grimm (2022).

Fig. B 2-9 Normalized RPS of alternative drive technologies in all drive system technologies of selected countries 2005, 2011, 2017

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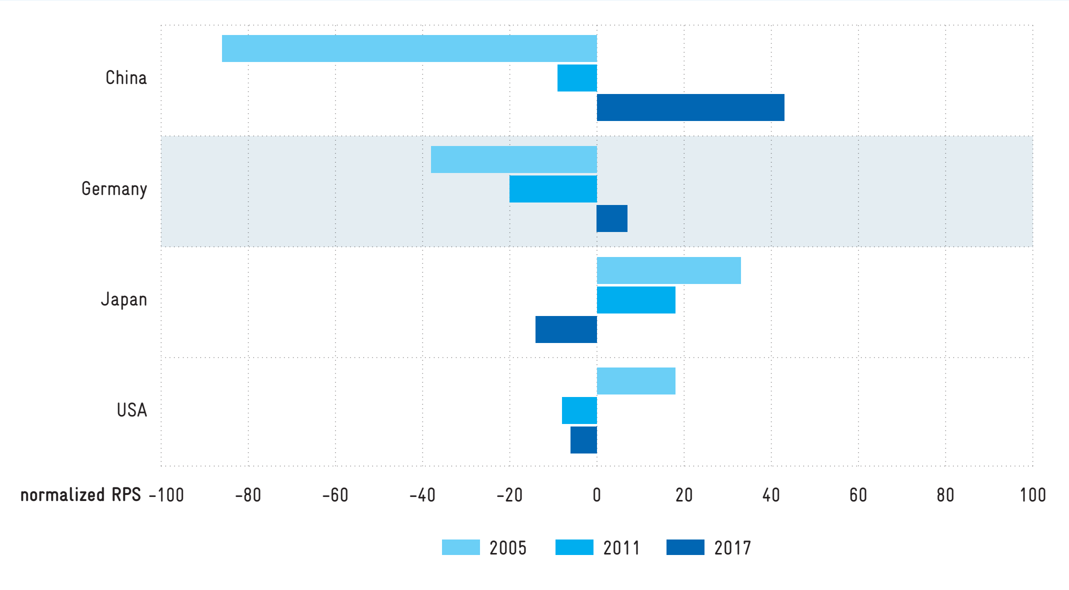

Normalized RPS of alternative drive technologies measured against all drive system technologies.
Legend: Japan has a normalized RPS of –14 in 2017. This value indicates that Japan's share of global patent applications in the field of alternative drive technologies this year is 86 percent of Japan's share of global patent applications in the field of all drive system technologies.
Source: PATSTAT. Own representation based on Sievers and Grimm (2022).

Rising Sales Figures for Alternative Drives

In addition to the innovation activity reflected in the patent applications, the market penetration of alternative drive technologies within individual countries is of great importance for a sustainability-oriented mobility transition. The development of the proportion of new registrations for the various drive systems in the period from 2010 to 2020 is examined below for Germany and selected comparative countries.

In 2020, there was a significant increase in the share of newly registered BEVs in Germany, starting from a low level, with an associated decline in new registrations of ICEVs (see figure B 2-10 a). As a result, in 2020 the share of BEVs sold in Germany was just under 6 percent, more than three times higher than in the previous year (see figure B 2-10 b). Germany was thus in the top group internationally in terms of the share of newly registered BEVs. This change is most likely also driven by the purchase premiums.[242] The share of ICEVs in vehicle sales was nevertheless still high at 85 percent.

However, by far the highest share of new BEV registrations in 2020 was registered in Norway with 42 percent. This high share of BEVs is due to various highly effective support measures. In Norway, the share of PHEVs in passenger car sales was also the highest in a global comparison at 16 percent. Here, Germany ranked second among the countries considered with a share of 7 percent (see figure B 2-10 c). In the case of pure hybrid vehicles (HEV), Japan recently recorded the highest share of new registrations with 20 percent, while this type of drive system hardly plays a role in Germany with a share of new registrations of less than 2 percent (see figure B 2-10 d).

Broad-based Promotion of Alternative Drives

The support measures in Germany regarding alternative drive systems focus primarily on battery electric drives. As the technology is well developed and ready for the market, current support focuses on greater market penetration. Important elements in the Government Programme on Electromobility (Regierungsprogramm Elektromobilität), which are promoted by the Länder and the Federal Government, but also by the EU, are purchase premiums, the expansion of the public and private charging infrastructure and the public procurement of electric vehicles, which are to make up at least 20 percent of the Federal Government's vehicle fleet.

In addition, in the area of alternative drive systems, the Federal Government and the Länder are supporting, to a considerably lesser extent, both research into vehicles powered by natural gas, hydrogen or fuel cells and their market launch.[243] In this context, the National Hydrogen Strategy (Nationale Wasserstoffstrategie) with the aim of accelerating the market ramp-up of new hydrogen technologies is of particular importance. In combination with alternative drive technologies, the use of new materials and processes in vehicle construction, for example by reducing the weight of the body and drive train, can also contribute to emission savings.[244] As part of the Technology Transfer Programme for Lightweight Construction (Technologietransfer-Programm Leichtbau), the Federal Ministry of Economics and Climate Protection (BMWK) supports cross-sector, cross-technology and cross-material research in the field of lightweight construction.

B 2-3 Automated and Autonomous Driving

Automated driving is an overarching term that encompasses both assisted and (partially) automated driving as well as completely driverless driving and the associated communication technologies that enable the networking of vehicles. Autonomous driving, as a sub-area of automated driving, describes the highest levels of automation, which include fully driverless driving and the associated communication technologies.

Change in Transport-related Emissions Due to Automated Driving

Advances in automated driving can contribute to a change in transport-related GHG emissions on two levels: gains in efficiency at the vehicle level (primary effects) and induced changes in mobility behaviour at the level of road users (secondary effects).

The main drivers of the primary effects, which increase with increasing degrees of vehicle automation, are harmonized driving characteristics, optimized engine control and the consideration of topography and traffic flow.[245] However, the efficiency gains through optimized driving behaviour are

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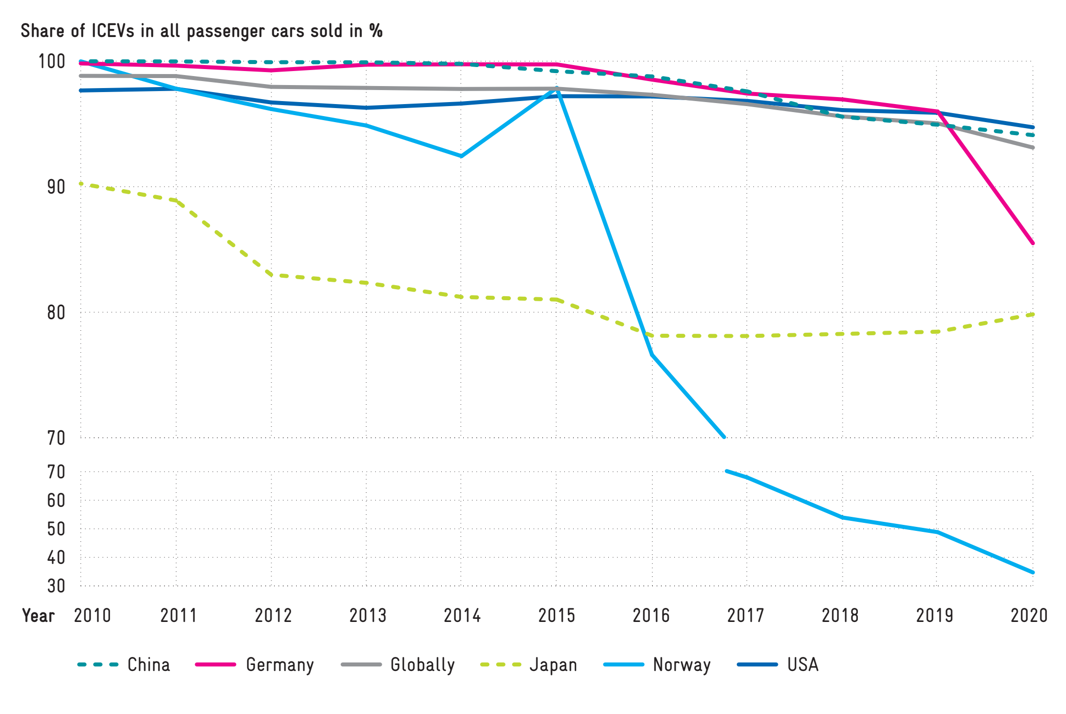
Fig. B 2-10 Share of conventional and alternative drive systems in passenger car sales in selected countries and worldwide 2010–2020 in percent

a) ICEV



b) BEV

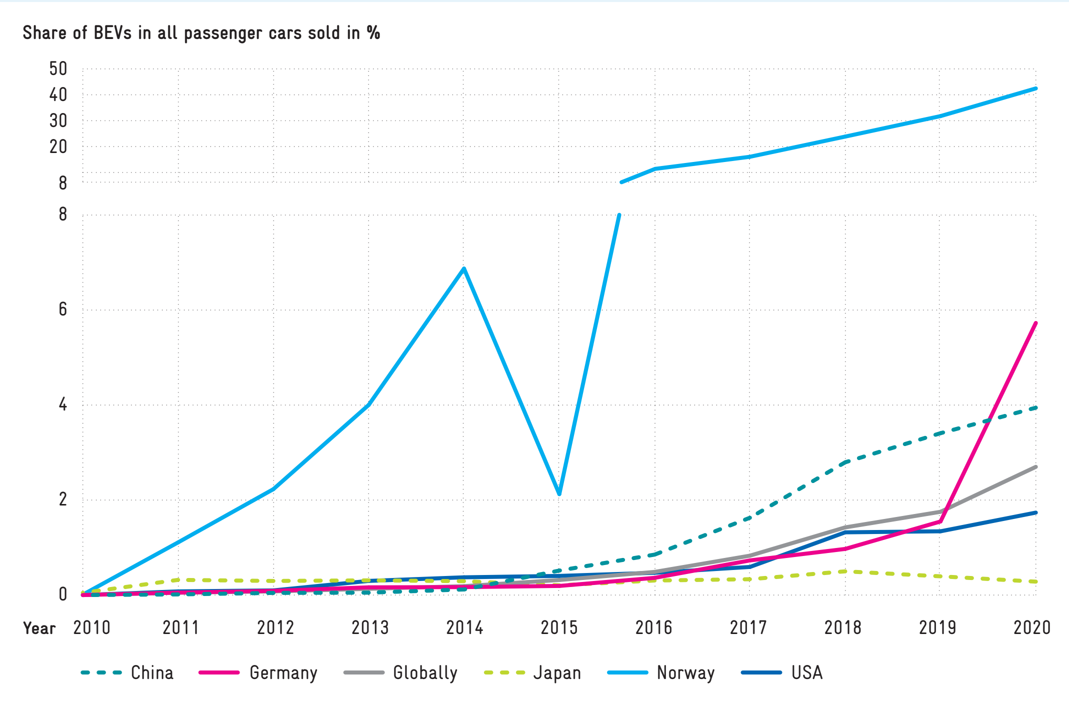
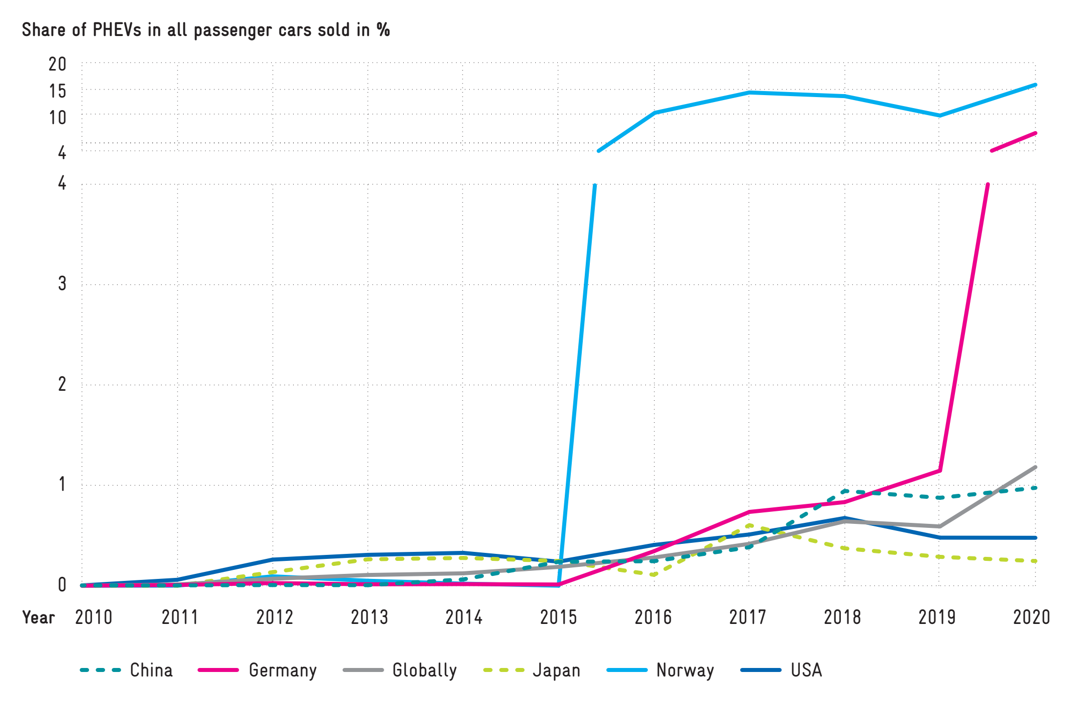


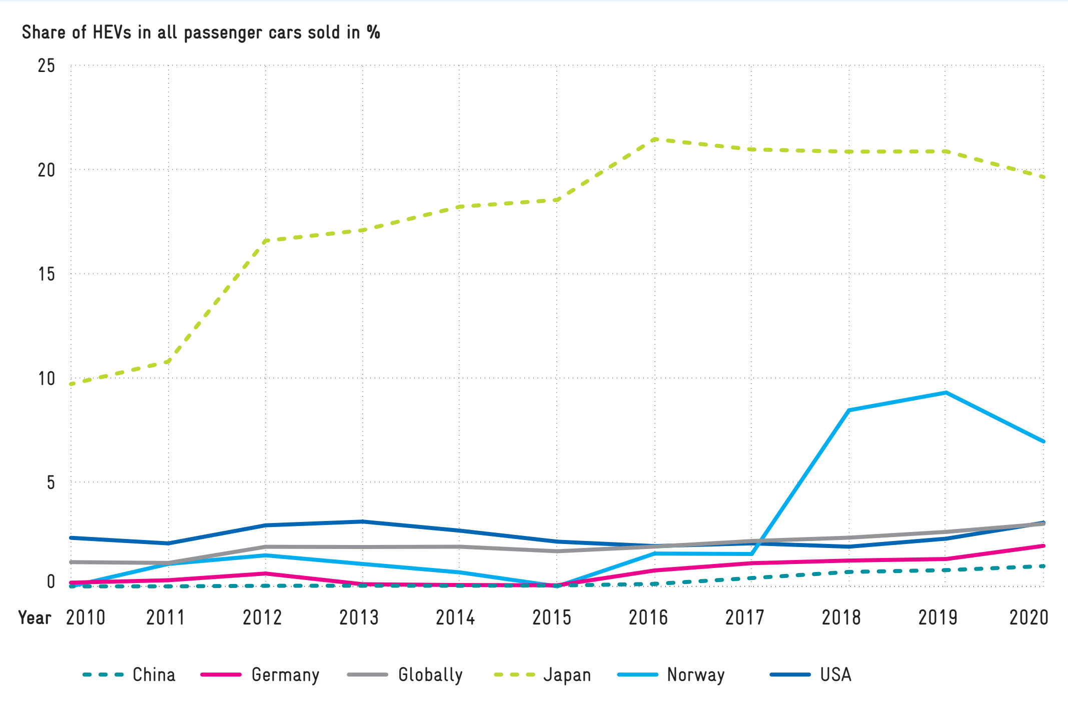
Fig. B 2-10 is continued on the following page.

Fig. B 2-10 Share of conventional and alternative drive systems in passenger car sales in selected countries and worldwide 2010–2020 in percent

c) PHEV



d) HEV



Source: Own representation based on Sievers and Grimm (2022).

partly offset by additional final energy consumption through networked automation systems, in the vehicles themselves as well as in mobile communications and in the digital infrastructure.[246]

Secondary effects arise because the efficiency and comfort benefits of automated vehicles change the relative attractiveness of transport modes. On the one hand, increased automation can lead to increased bundling of on-demand transport and thus lower mileage and GHG emissions. On the other hand, a growing share of private transport and the development of new user groups can lead to increased mileage of automated vehicles and thus increase emissions again, a so-called rebound effect.[247]

Traditional Automotive Nations Lead the Way in Automated Driving

In the period from 2005 to 2018[248] there was a significant increase in transnational patent applications in the field of automated driving (see figure B 2-11).[249] Initially, the development was driven primarily by patent applications in the field of assistance technologies, while in the further course patents on autonomous driving have become more important (see figure B 2-12). The increase in patent applications in the field of automated driving has been noticeable in Germany and Japan since 2008. In the USA, the development has only gained strong momentum since 2013. The USA and Germany have recently overtaken the previous leader Japan, with Germany only just behind the USA. China and South Korea follow at an already marked distance. However, five years earlier, both countries hardly played a role internationally in transnational patent applications in the field of automated driving and have quickly left France and the UK behind.

Development of Autonomous Driving in the USA Highly Dynamic

Germany was the international leader in transnational patent applications in the subfield of autonomous driving until around 2010 (see figure B 2-12). After that, however, the leading position was lost to the USA, which, after a highly dynamic development, recently filed the most patents in this field by a wide margin. It is true that the number of transnational patent applications from Germany in the field of autonomous driving more than trebled between 2014 and 2018, meaning that Germany has pulled clear of Japan and South Korea. However, in 2018, Germany filed less than half as many patent applications as the USA.

Automated and Autonomous Driving Supported

Innovations in the field of automated and autonomous driving are supported by a large number of support programmes, particularly at the federal level. The funding is concerted under the Federal Government's Strategy for Autonomous and Connected Driving (Strategie autonomes und vernetztes Fahren) implemented by the Federal Ministry of Transport and Digital Infrastructure (BMVI), which was launched back in 2015. The aim of the strategy is to make Germany the lead market and lead provider in automated and interconnected driving. To this end, among other things, the legal framework has been expanded, test fields for automated vehicles funded by the Federal Government and the Länder have been established[250] and R&D projects on both technical and social aspects of automated driving have been supported.[251]

To promote innovations in the field of autonomous driving, the BMVI has set up a funding guideline with a volume of €122 million in 2019 with the aim of further developing higher levels of automation up to autonomous driving and artificial intelligence in automobility. Since November 2021, the Federal Ministry of Education and Research (BMBF) has been funding software development for the digitalization of automobility with a total of €135 million, which also enables the further development of automated vehicles.[252]

German Legal Framework for Autonomous Driving Leads the Way

With the Act on Autonomous Driving (Gesetz zum autonomen Fahren), which came into force in July 2021, Germany is the first country in the world to have a legal basis for the regular operation of highly automated vehicles without a driver in specified operating areas.[253] This legal framework improves the conditions for the market launch of highly automated vehicles.[254] This puts Germany in a position to help shape the development of autonomous vehicle systems as a technology driver and to provide incentives for car manufacturers to develop such systems.[255]

Fig. B 2-11 Number of transnational patent applications in the field of automated driving in selected countries 2005–2018

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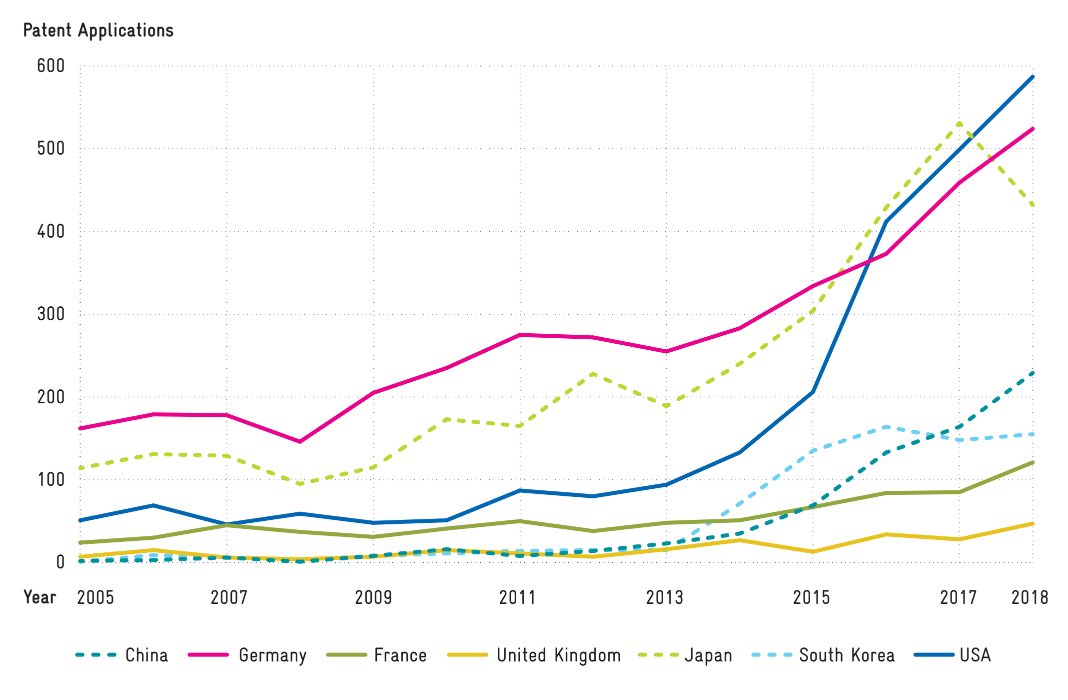

Source: PATSTAT. Own representation based on Sievers and Grimm (2022).

Fig. B 2-12 Number of transnational patent applications in the field of autonomous driving in selected countries 2005–2018

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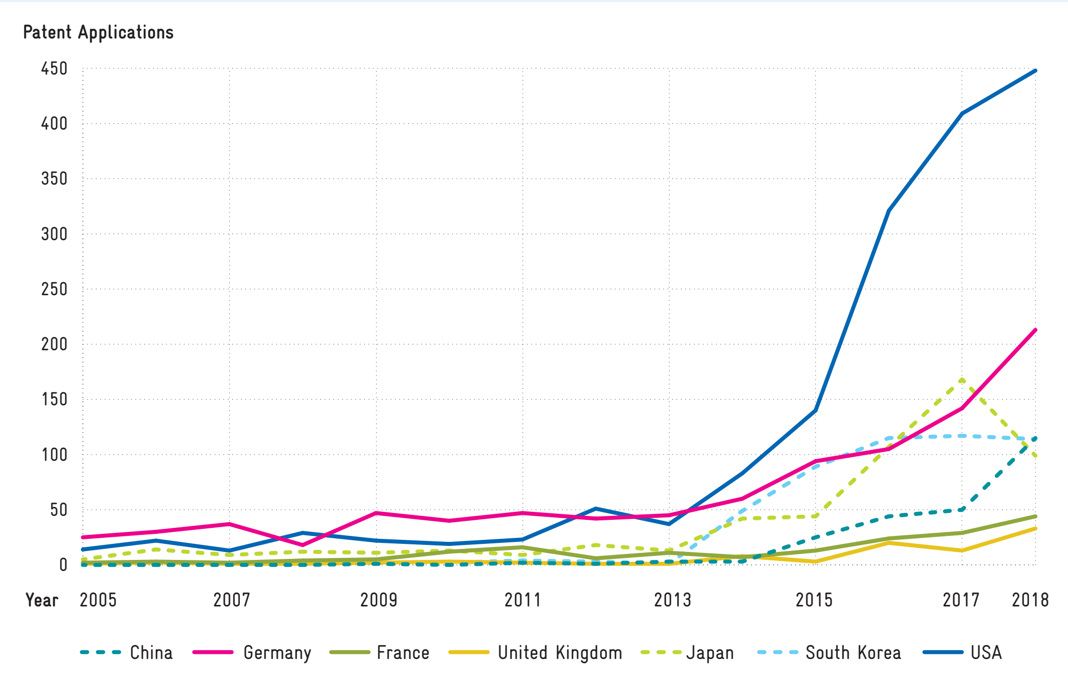


Source: PATSTAT. Own representation based on Sievers and Grimm (2022).

B 2-4 Sharing Services in the German Mobility Landscape

GHG emission reductions can be achieved not only through new lower-emission vehicle technologies, but also through behavioural changes in the choice of transport modes. Although currently a good three quarters of all German households own their own car,[256] calls for a rethink towards sharing instead of owning, that is, the sharing of means of transport, are growing louder.[257] These demands are based on two facts: Private cars remain unused for most of the day, and the majority of car journeys involve the transport of only one person. At the same time, many people travel identical routes or sections of routes during peak traffic times, so it is obvious to share means of transport in order to conserve resources.

There are numerous business models that aim to improve the utilization of private cars. These include platform models that offer the coordination of shared journeys and carpooling.[258] In addition, sharing models have emerged in recent years that challenge the character of the car as a primarily individually used means of transport in private ownership. These include, above all, car sharing and ride pooling. Car sharing is the organized collective use of vehicles held by a provider who usually does not use them themselves and who has sole responsibility for the functioning of the vehicles.[259] Thus, car sharing is usually not the sharing of a commonly owned resource, but a commercial service offering in which the vehicles are available for sequential use by different people. Car sharing is now also offered by the major car rental companies and sometimes even by car manufacturers.[260] In addition, there is a range of usage subscriptions with terms ranging from a few hours to several months, creating a smooth transition from individual to shared use.

Ride pooling is a form of bundled transport, usually to transport several passengers flexibly between stops in an area as needed.[261, 262] Ride pooling is subject to the Passenger Transport Act (Personenbeförderungsgesetz, PBefG) and includes both bundled on-demand transport that is not part of local public transport and scheduled on-demand transport as part of local public transport.[263]

Density of Supply and Use of Sharing Services Still Low

In the case of car sharing, the supply in Germany currently reaches an average density of 33 vehicles per 100,000 inhabitants.[264] In the case of ride pooling, the average value is approximately one vehicle per 100,000 inhabitants. However, individual municipalities have much higher densities.[265] According to a representative survey in major German cities, car sharing was regularly used by 4 percent, but ride pooling by only 2 percent.[266]

Framework Conditions for Greater Use of Sharing Services

To clarify the extent to which politically adjustable factors can increase the use rates of car sharing and ride pooling and how a change in the use of these offers affects the structure of transport use, the Commission of Experts commissioned a simulation study.[267] Starting from the status quo, the effects of a combined change in the CO_2 price with an increase in fuel tax and subsidies for emission-free passenger cars were examined. In another scenario, the effects of an increase in parking fees and the parallel levying of tolls in the city area were analyzed. In addition, increased promotion of local public transport through the combination of higher frequency, a halving of transport fares and a reduction of waiting times was simulated.

Comparing these combined measures, raising the CO_2 price, fuel tax and subsidies for zero-emission cars causes the strongest increase in the usage shares of car sharing and ride pooling. A combination of these measures with higher parking and toll charges proves to be particularly effective. However, the effects of the examined instruments[268] remain very restrained overall. By 2030, usage shares of a maximum of 1.8 percent are expected for car sharing. For ride pooling, the usage shares are even lower, with a maximum of 0.3 percent. Both types of sharing services do not cover their costs, so they remain uneconomical without subsidies. All in all, car sharing and ride pooling do not appear to be in a position to establish themselves as alternatives to the use of one's own car in the foreseeable future. However, the expected growth in the use of car sharing and ride pooling is significantly higher in urban areas than in rural areas.

Ride pooling could be a cheaper alternative to existing local public transport services, especially in rural areas. The increased use of smaller, more flexible and better utilized vehicles could have positive environmental effects. Currently, a broader offer of ride pooling services still fails due to the high capital and personnel costs for additional vehicles.[269] However, personnel costs in particular could decrease significantly in the future due to new technologies such as autonomous driving, so that the profitability of the services would increase.

However, possible rebound effects must be taken into account.[270] It is to be expected that people who currently do not drive themselves at all or only rarely will make more frequent use of driving services by driverless vehicles if costs fall. Even though there are no studies on this yet due to a lack of data, it is known from other contexts that such rebound effects can be counteracted with suitable pricing, in this case a combination of CO_2 price and a road toll system.[271]

Unlike scheduled on-demand transport and taxi transport, bundled on-demand transport does not fall under local public transport according to the Passenger Transport Act (PBefG). It is therefore at a disadvantage compared to these. Journeys in bundled on-demand transport are subject to a VAT rate of 19 percent, while journeys in local public transport are only subject to 7 percent VAT. In addition, bundled on-demand transport can be partially restricted in operation by municipal control mechanisms.[272] This creates uncertainties for mobility service providers and inhibits the expansion of innovative ride pooling services.[273]

On a positive note, the new Passenger Transport Act (PBefG) regulates the collection of mobility data, which is to be available to both authorities and mobility service providers within the framework of the 'Mobilithek'.[274, 275] This will enable the development of mobility concepts based on the networking of mobility data, such as intermodal route planning. However, a data interface with GAIA-X is not yet planned.

B 2-5 Recommendations for Action

The development towards sustainable motorized private transport is reliant on progress in lower-emission drive systems. The battery-powered car is proving to be the most ecologically and economically advantageous alternative. Accordingly, it is important to increase the use of this drive system in order to increase its attractiveness and acceptance as a result of network effects. In addition, developments in digitalization and autonomous driving open up opportunities for innovative mobility services in order to contribute to the reduction of emissions by bundling transport. The Commission of Experts therefore recommends the following measures to promote sustainable individual transport:

Setting Adequate Transport and Climate Policy Incentives and Increasing the Supply of CO_2-neutral Electricity

Since battery-powered electromobility for motorized private transport is currently emerging as both the most ecologically effective and the most economical of the lower-emission drive systems, its appeal should be increased compared to conventional internal combustion engines.

— To reduce the desirability of conventional internal combustion engines and at the same time give companies planning security with regard to the marketability of e-mobility and future developments of alternative drive systems, a sufficiently high CO_2 price should be implemented as quickly as possible by means of suitable measures (cf. chapter A 1).

— The Commission of Experts encourages the Federal Government to increase the supply of CO_2-neutral electricity, as intended in the coalition agreement, by expanding renewable electricity sources, among other things.

— To keep electricity prices low, electricity should be exempted from additional burdens without a steering effect, such as the EEG levy and the electricity tax.

Increasing Support for R&D on Sustainable Battery Technology and New Materials

— The current generation of batteries still entails considerable negative ecological effects in producing countries. The development of new types of batteries with a lower ecological footprint should be vigorously promoted.

- The new Federal Government should push for the establishment of corresponding environmental standards for imported batteries at the European level.

- Innovations and technological developments should continue to be promoted with regard to new materials, especially for weight reduction and resource-saving vehicle designs, in order to contribute to increasing battery ranges.

Expanding Public Charging Infrastructure and Establishing Transparency of Payment Systems

- In addition to the publicly funded expansion of the charging infrastructure, the Commission of Experts recommends that the Federal Government advocate transparent pricing structures at charging stations to promote the acceptance and market penetration of battery electric vehicles.

- Due to the high resource requirements of fuel cell passenger cars and due to expected technological innovations in the transport and storage of hydrogen, which may enable the use of existing infrastructure, there is currently no urgent need for action to expand the hydrogen filling station network for passenger cars with public funds.

Reforming the System of Purchase Premiums and Vehicle Taxation

In principle, purchase premiums are suitable for increasing the share of newly registered vehicles with alternative drive systems. However, stronger purchase incentives can be created through direct pricing of externalities and road use charges.

- The current purchase premium system should be phased out by 2025 as planned.

- Plug-in hybrids should be immediately excluded from purchase premiums, as they perform significantly worse in the life cycle assessments than battery electric vehicles.

- Pricing of CO_2 and other externalities should be achieved through a combination of a CO_2 price and a correspondingly adjusted petrol/diesel tax.

- The system of taxes and charges for road transport should be fundamentally reformed by replacing flat-rate vehicle taxes in the medium term with direct use charges, i. e. a comprehensive road toll system.

Improving Competitive Conditions for Bundled On-demand Transport

Various statutory regulations and ordinances have so far hampered the economic operation and development of innovative business models for bundled on-demand transport.

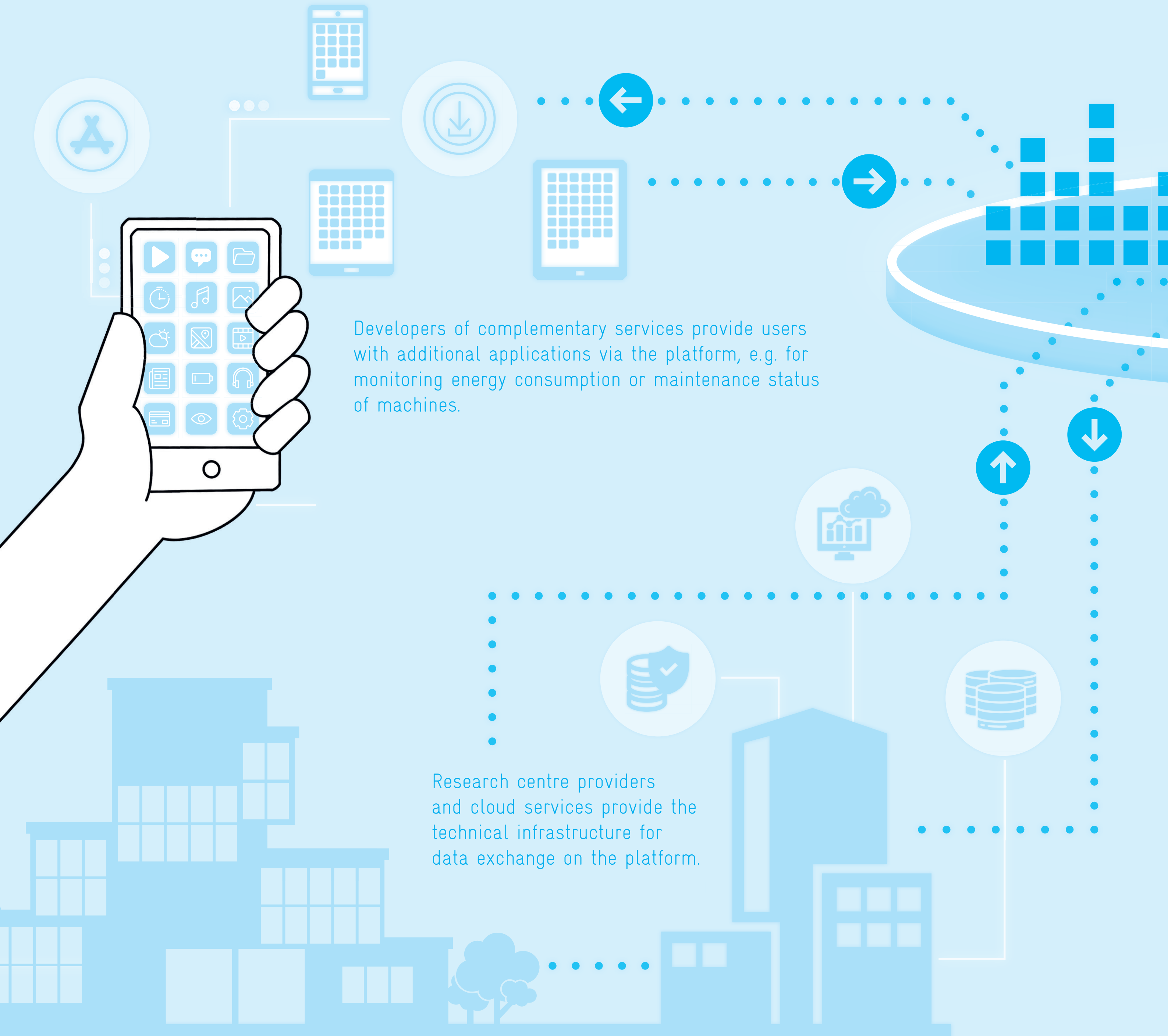
- Section 50 of the Passenger Transport Act (PBefG) should be reformed so that municipalities can exert less influence on bundled on-demand transport.

- Bundled on-demand transport and taxi services should be treated equally for tax purposes.

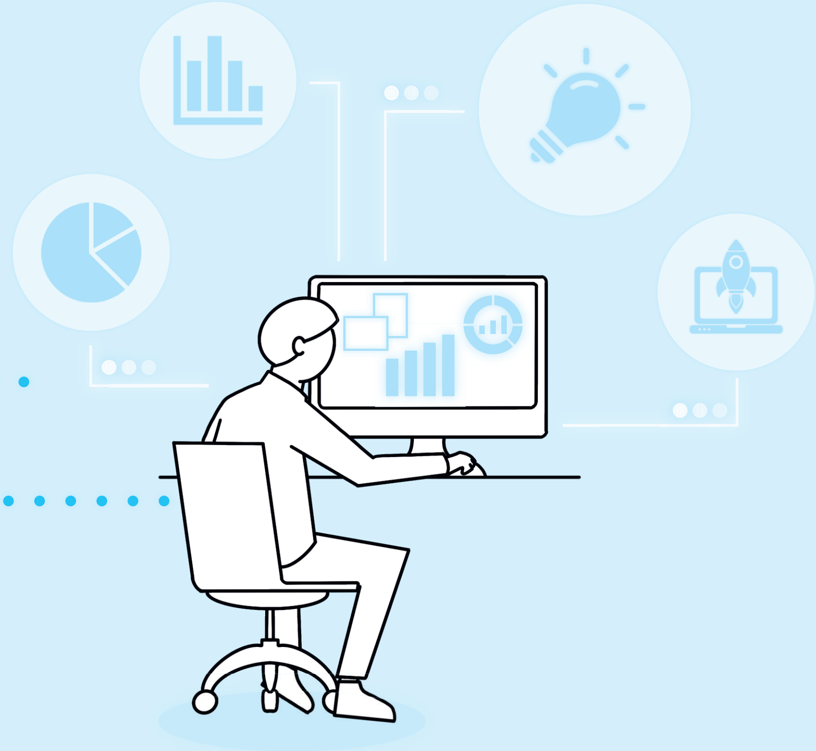
B 3 Innovations in the Platform Economy

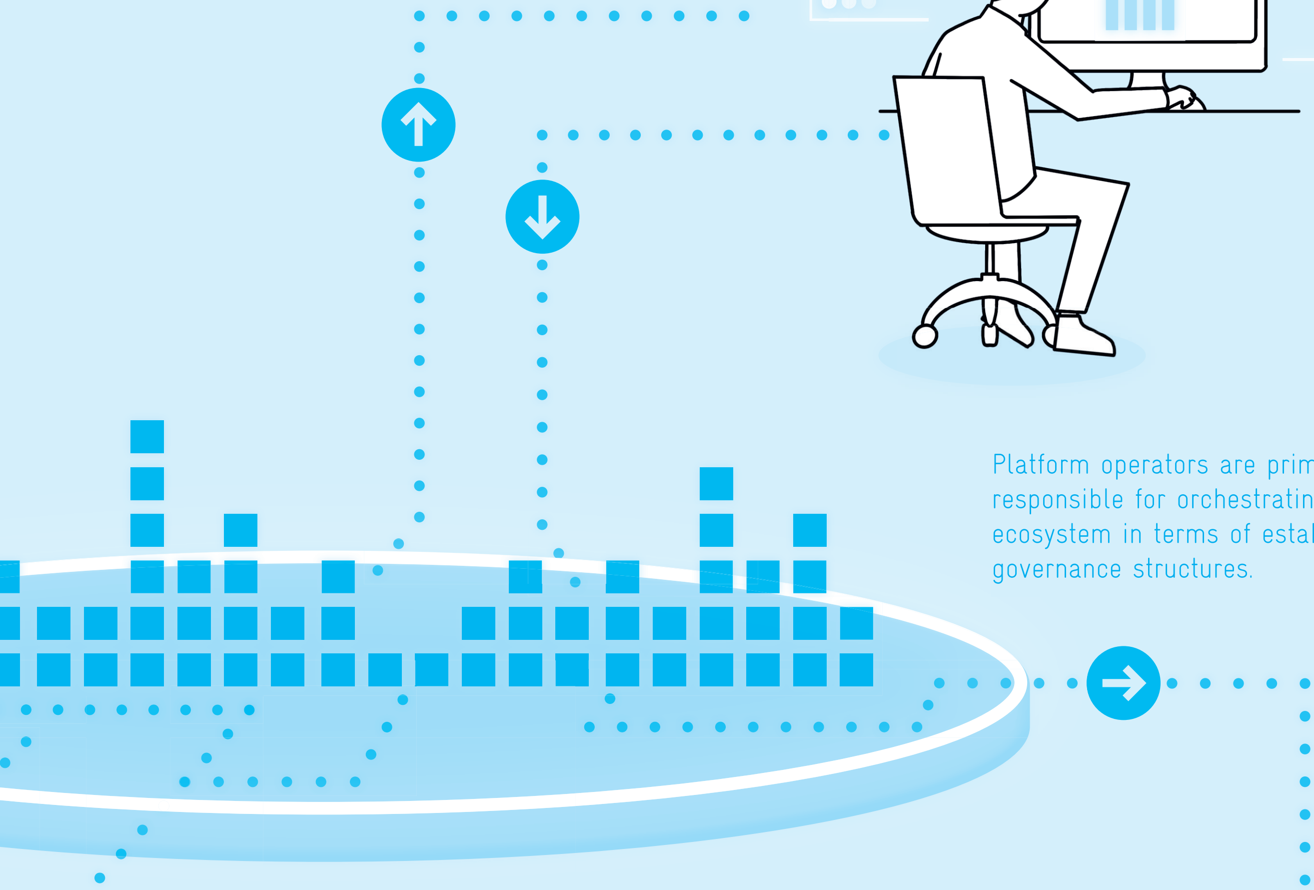
Download Data

Digital platforms orchestrate the interaction of different stakeholder groups and enable the development of innovative business models as well as new products and services. Data are a key value-creation factor in this context. B2B platforms in particular open up great potential, through the use of which efficiency gains in production can be realized and innovation and value creation processes can be redesigned and further developed.



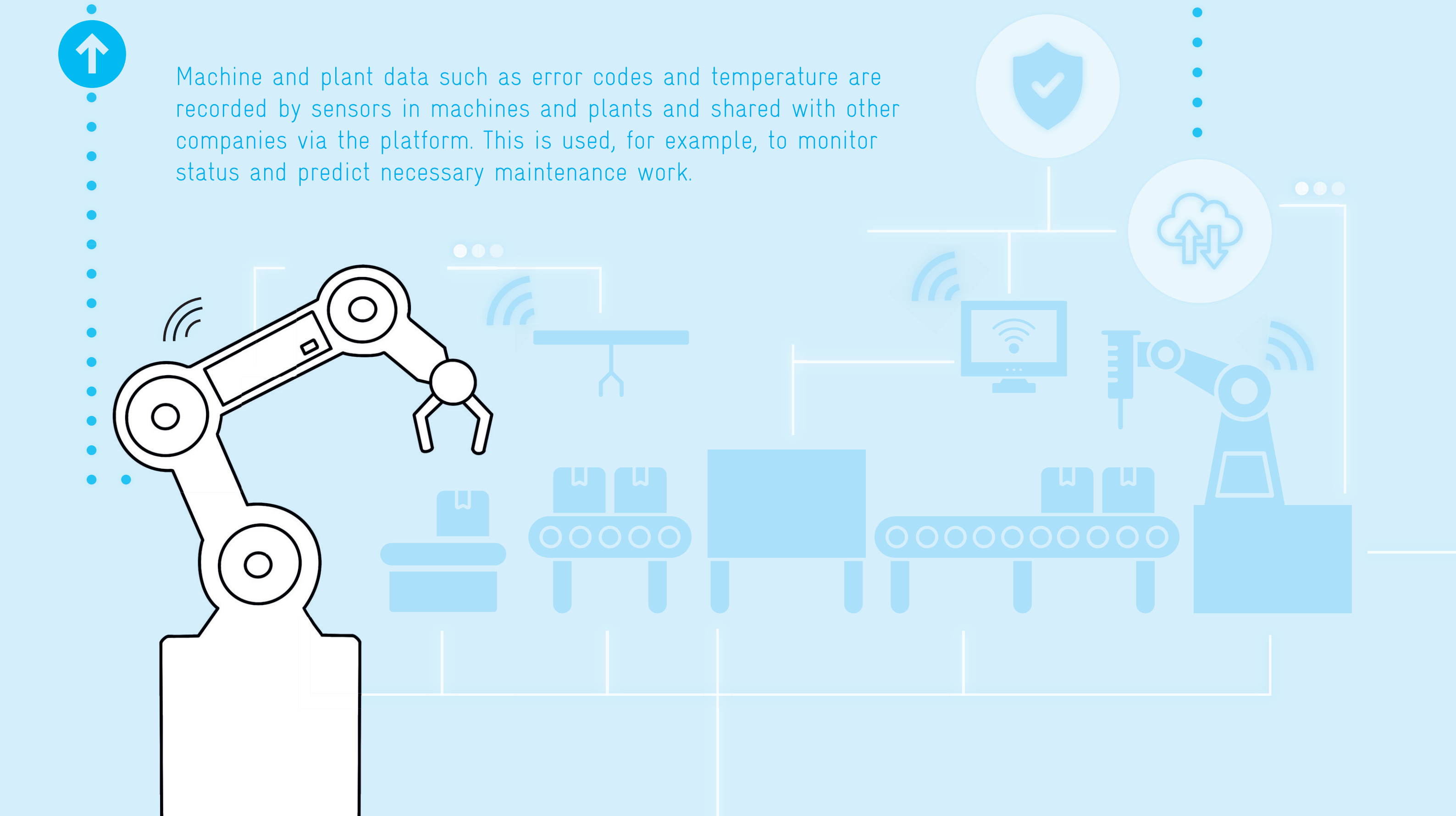
Start-ups and young companies can use the data shared via the platform to train new algorithms or develop new business models.





Platform operators are primarily responsible for orchestrating the platform ecosystem in terms of establishing governance structures.

Machine and plant data such as error codes and temperature are recorded by sensors in machines and plants and shared with other companies via the platform. This is used, for example, to monitor status and predict necessary maintenance work.



B 3 Innovations in the Platform Economy

The major US platform companies Alphabet (Google), Amazon, Apple, Meta (Facebook) and Microsoft are among the most profitable companies in the world in terms of stock market value. They orchestrate the digital interaction of different groups of stakeholders and, largely based on the data generated on their platforms, develop innovative products, services and business models, change value chains, and achieve dominant market positions.

In contrast to these large platform companies, which are particularly active in the business-to-consumer (B2C) sector, pure business-to-business (B2B) platforms are usually focused on specific industries or applications. But they too are changing value chains, creating new business models and generating new products and services. Companies that use digital B2B platforms see many advantages for their own innovation activities, for example, through simplified access to data and the integration of external partners in the innovation process.

However, B2B platform use by businesses faces several barriers. In particular, companies have concerns about data protection and IT security when using B2B platforms and fear the outflow of knowledge relevant to innovation and competition. In addition, in the B2B context there is a lack of mutual trust between the companies networking through the platform as well as the fear of one-sided dependencies. Further obstacles are the lack of standards and interoperability between platforms.

The potential for value creation by means of B2B platforms and especially using data-based platforms in the industrial sector is estimated to be high for the German economy. It is based on the high level of industry-specific knowledge and innovation potential that results from access to extensive production and machine data of German companies. According to estimates, the contribution of digital B2B platforms to gross value added in manufacturing amounted to 1.5 percent in 2018. If the diffusion of these B2B platforms continues at the expected rate, this contribution could be expected to double to up to 3 percent in 2024.[276]

The potential associated with B2B platforms must be leveraged and a drain of value creation by German companies to the established B2C platforms from the USA and China, which are increasingly penetrating the B2B sector, must be avoided. In order for the German economy to better leverage innovation and value creation potential in the B2B platform economy, the regulatory framework needs to be adapted and targeted stimuli from the public sector need to be provided.

B 3-1 Characteristics, Classification and Distribution of Digital Platforms

A platform[277] brings actors together and actively manages the interaction between them.[278] The term platform is often used synonymously with the term multi-sided market, where different groups of actors meet. Platforms are characterized by so-called network effects, i. e. the benefit of platform actors depends on the number of actors on the platform.[279] With digital platforms, the interaction between actors takes place on an internet and data basis.[280] This makes it easier to find suitable interaction partners. In addition, the coordination effort between the individual actors is reduced by standards set by the platform for communication, data exchange and contract execution. The platform economy encompasses the totality of all activities and stakeholders around platforms, including all economic processes.

From Digital Platform to Platform Ecosystem

The particular added value of digital platforms is based on network effects, economies of scale and economies of scope. Positive direct network effects arise when the benefit of platform actors increases with the number of actors in the same group of actors.[281] If the benefit of a group of actors increases due to the increasing number of actors in another group of actors, these are positive indirect network effects. Amazon, for example, is all the more attractive for sellers the more potential buyers use this platform, as this leads to expectations of higher sales. At the same time, the more sellers offer their products or services there and contribute to a greater variety of offers, the more attractive Amazon is for buyers. Economies of scale arise because the development of digital products is associated with high fixed costs but low reproduction costs.[282] For example, the development of a search engine is very costly, but a single additional search query can be served at negligible cost. Economies of scope occur when a platform company operating in one market can, for example, also offer new products and services in another market with the help of the data collected there.[283]

The interplay of these characteristics leads to the emergence of platform ecosystems. These are composed of the platform as the technical infrastructure (e.g. Android as a software platform), the platform operator (e.g. Alphabet), the various providers (e.g. mobile phone manufacturers), the developers of complementary services (e.g. app developers) and the customers (e.g. app users).[284] The platform operators are primarily responsible for orchestrating the platform ecosystem in the sense of establishing governance structures.[285] Platform ecosystems are characterized by a modular structure. New providers and developers can expand the ecosystem with new products and services. This leads to an opening up and further development of the innovation and value creation processes.[286] An important goal of governance is to ensure the quality of complementary offerings, to regulate who has access to a platform, how providers can present their offerings, and which data and application programming interfaces (API) may be accessed.

Data are an essential resource in the platform ecosystem and for platform-based business models. They are non-rivalrous in their usage, i.e. several actors can use the same data without using it up.[287] At the same time, actors can be excluded from data usage, for example, through technical restrictions. Due to these two characteristics, non-rivalry in usage and excludability from usage, data represent a so-called club good. Data can help companies develop new products and services, improve existing products and services, make processes more efficient and make better decisions or predictions.[288]

B2B platforms cannot always be clearly distinguished from the larger B2C platforms such as Amazon and Alibaba, as B2B platforms sometimes also offer B2C solutions or vice versa. Some structural differences between B2B platforms, especially in the industrial sector, and typical B2C platforms can nevertheless be identified.[289] First of all, the importance of a single user in the B2B sector is significantly higher for the platform's revenue and profit. Therefore, B2B platforms often develop individualized offers and contracts for their users. The scaling advantages are therefore comparatively small.[290] Due to the transfer and use of sensitive, often competition-relevant corporate data, the requirements for data security are particularly high, which is why trust is even more important when using B2B platforms. Consequently, a large proportion of industry platform users rely on company-owned, closed platforms.[291] Platforms in the industrial sector in particular often focus on specific fields of application and industries.

B2B Platforms with Diverse Usage Potentials

Platforms can be classified in different ways. In addition to the target group addressed by a platform and the function fulfilled by the platform, the degree of openness of a platform is a possible distinguishing feature.[292] If access to a platform is open to all actors without conditions, it is an open platform. For security, data protection or quality reasons, it may make sense for platform operators to grant access to the platform only to certain users. This is called a closed or semi-open platform.

The platforms described below are explicitly aimed at corporate customers (B2B platforms) and can be differentiated according to three main types: transaction platforms, data-based platforms, and innovation platforms. Although all three platform

Box B 3-1 Examples of B2B Platforms

XOM Materials as a Transaction Platform
XOM Materials is an open and industry-specific B2B transaction platform founded by steel trader Klöckner & Co SE, where transactions involving steel and metal products can be initiated and processed.[293] The platform went online in Europe in 2018 and is used for trading between large steel producers, traders, and processors. XOM Materials operates independently of Klöckner to ensure that Klöckner does not have access to sensitive data from competitors. From a customer perspective, the platform offers a comprehensive range of products provided by numerous suppliers. In addition, there is the possibility of concluding customer-specific contractual agreements. This facilitates and optimizes procurement processes. Sellers benefit from a high international reach as well as more efficient sales processes, for example through bundled order management.

Data Intelligence Hub as a Data Marketplace
In 2018, Deutsche Telekom AG launched its B2B platform Data Intelligence Hub (DIH).[294] On a secure data infrastructure, non-personal data can be exchanged between different groups of actors across industries. In addition to Deutsche Telekom as the platform operator, the platform ecosystem includes providers of data sets from various sectors such as healthcare, manufacturing, logistics and tourism. In addition to the datasets made available by the providers, the consumers also use the data workspaces and data analysis services provided in the DIH (e.g. Azure Databricks). The DIH is an open B2B platform, as anyone can register and no restrictions are imposed by the platform operator. Due to its open structure, the DIH enables cross-sectoral data exchange, which facilitates innovation and value creation potentials.

MindSphere as an IoT Platform
The B2B platform MindSphere has been maintained by Siemens AG since 2015 as a cross-industry and open platform.[295] MindSphere allows IoT data from different machines, plants and systems in a company to be collected and connected with each other.[296] The data can then be analyzed with applications offered on the platform to optimize processes and increase efficiency, for example.
The user group in the platform ecosystem consists primarily of manufacturing companies and development service providers that use MindSphere to expand their digital product offering and improve their technical infrastructure.[297] Both Siemens AG and various partner companies and developers of complementary services provide users with additional applications, e.g. for monitoring energy consumption and maintenance status.

types enable innovation activities with the aim of developing new products, services and processes, innovation platforms explicitly focus on the joint development of innovations and the improvement of innovation processes.

Transaction platforms are digital marketplaces where goods and services are traded. For buyers, transaction platforms offer the opportunity to simplify and standardize purchasing processes and thus reduce their transaction costs. Sellers benefit in particular from tapping into new customer groups active on the platform and thereby increasing their reach (for an example see box B 3-1).[298] A representative survey[299] conducted on behalf of the Commission of Experts shows that companies in the German economy currently use transaction platforms most frequently for B2B interactions (see figure B 3-2). 53 percent of companies in the information economy and 50 percent of companies in the manufacturing sector use transaction platforms to purchase products or services. For the sale of products or services, just under 8 percent of companies in the information economy and 12 percent of companies in the manufacturing sector use such platforms.

Several types of data-based platforms can be distinguished. The most important are platforms for cloud services, data marketplaces and platforms in the industrial Internet of Things (IoT), so-called IoT platforms.

Cloud service platforms enable the protected storage of data, which allows both exclusive storage without data access for third parties and the

Fig. B 3-2 Purpose of using digital platforms in the B2B sector

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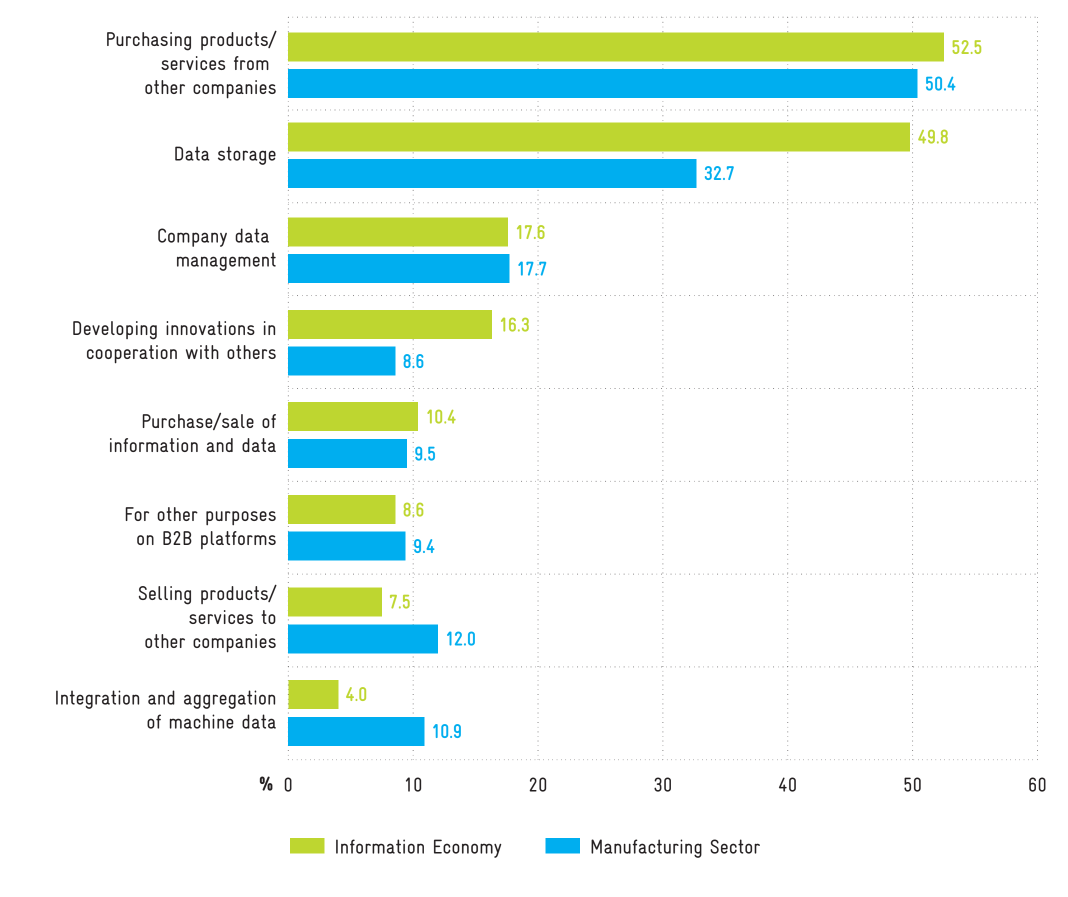

Sector-specific extrapolation of the results to the question: 'Does your company use digital 'business-to-business' (B2B) platforms for one or more of the following purposes?' Multiple answers possible. Legend: 50.4 percent of manufacturing companies use digital platforms in the B2B sector to purchase products/services from other companies.
Source: ZEW Business Survey in the Information Economy (ZEW Konjunkturumfrage), 3rd quarter 2021.

selective sharing of data. Here, data are stored on external servers meaning that the technical possibilities do not depend on internal equipment and access is usually possible regardless of location. In the above-mentioned survey, 50 percent of companies in the information economy and 33 percent of companies in the manufacturing sector stated that they use B2B platforms to store data. For the data management of their own company, 18 percent of companies in the information economy and in the manufacturing sector each use B2B platforms.

Data marketplaces are used to trade, exchange and share information and data, on the basis of which companies can innovate and generate additional value.[300] Data marketplaces are currently still in a very early phase of development. One of the first examples is Deutsche Telekom's cross-sector Data Intelligence Hub (DIH), which has been on the market since 2018 (see box B 3-1). In the German economy, data marketplaces have so far been used less frequently than platforms for transaction processing or data storage. According to the above-mentioned survey, around one in ten companies in the information economy and manufacturing sector is active on data marketplaces.

Due to the high value-added contribution of the manufacturing sector, great importance is attached to industrial IoT platforms in Germany and Western Europe. For example, IoT platforms enable companies in the machinery and plant engineering and manufacturing industries to share machine and plant data across industries for status monitoring and predicting necessary maintenance and to analyze it using AI-powered algorithms.[301] Data such as error codes, movements and temperature are collected by sensors in machines and equipment. Based on the comparison with reference values, the condition of a plant can be continuously monitored and directly readjusted if necessary (see box B 3-1 for an example). Studies estimate the Western European market for IoT platforms in 2019 at around €3 billion and the average annual growth rate up to 2024 at 11 percent.[302] According to the companies in the above-mentioned survey, 4 percent of companies in the information economy and 11 percent of companies in the manufacturing sector currently use B2B platforms for the purpose of integrating and aggregating machine data.

German economy also uses innovation platforms. The focus here is on the joint development of innovations and improvement of the innovation process. For example, CrowdWorx GmbH provides an innovation platform where companies can develop products and services collaboratively in an open innovation process.[303] Another international example is the GitHub platform. On this platform, companies can host software projects, share them with others and work together on projects.[304] According to the survey conducted on behalf of the Commission of Experts, 16 percent of companies in the information economy and 9 percent of companies in the manufacturing sector use B2B platforms for the joint development of innovations.

B 3-2 Competition and Innovation in the Platform Economy

Within a platform ecosystem, different actors contribute to the emergence of innovations. Actors include both the platform operators themselves and other companies that offer complementary services on the platform or use the platform to improve their processes or develop new products and business models.

Network effects and economies of scale can ensure that only a few platform operators compete with each other in a market. In extreme cases, the market tilts, and only one platform operator remains (so-called winner-takes-all effect).[305] Platform operators often pursue an aggressive growth strategy to quickly reach a critical mass of users and to bind them to their own platform with standards, among other things (so-called lock-in effects), resulting in market entry barriers. These developments can have different effects on the innovation activities of platform operators.

Low competition may mean that dominant platform operators have little incentive to invest in research and innovation and to further improve the quality of their products and services.[306] At the same time, fewer innovations are generated by new market entries. This further restricts competition in the market, where mostly incremental innovations take place. Competition between platforms in the market can be favoured by actors using different platforms at the same time (so-called multihoming), thereby mitigating lock-in effects. Multihoming is made possible on the one hand by the interoperability of platforms, which is brought about by means of standardized technical interfaces. On the other hand, so-called data portability facilitates multihoming, i. e. the possibility for actors to transfer their data from one platform to another.[307]

Innovations can also arise from platform operators entering neighbouring markets with new offers. These innovations are based, for example, on data that the platform operator has collected in the established market. Another way to tap into a new market through innovation is to acquire other companies. However, takeovers can also serve to eliminate potential competitors and prevent innovations from start-ups from gaining acceptance on the market. In this way, the established platform operator can further expand its dominant position. A disruptive innovation can challenge this position. In this case, competition for the market takes place.[308]

B2B Platforms Advantageous for Innovation Activity

The use of platforms can positively impact the innovation activities of platform users if a platform ecosystem creates conditions conducive to innovation.[309] In the survey conducted on behalf of the Commission of Experts, companies were asked about the positive or potentially positive effects of B2B platform use on innovation activities and factors relevant to innovation. Simplified access to data is seen as the most important advantage of platform use both in the information economy and in the manufacturing sector. Companies that use platforms rate the simplified access to data positively much more often than companies that do not use platforms (see figure B 3-3). Among platform-using companies in the information economy, the

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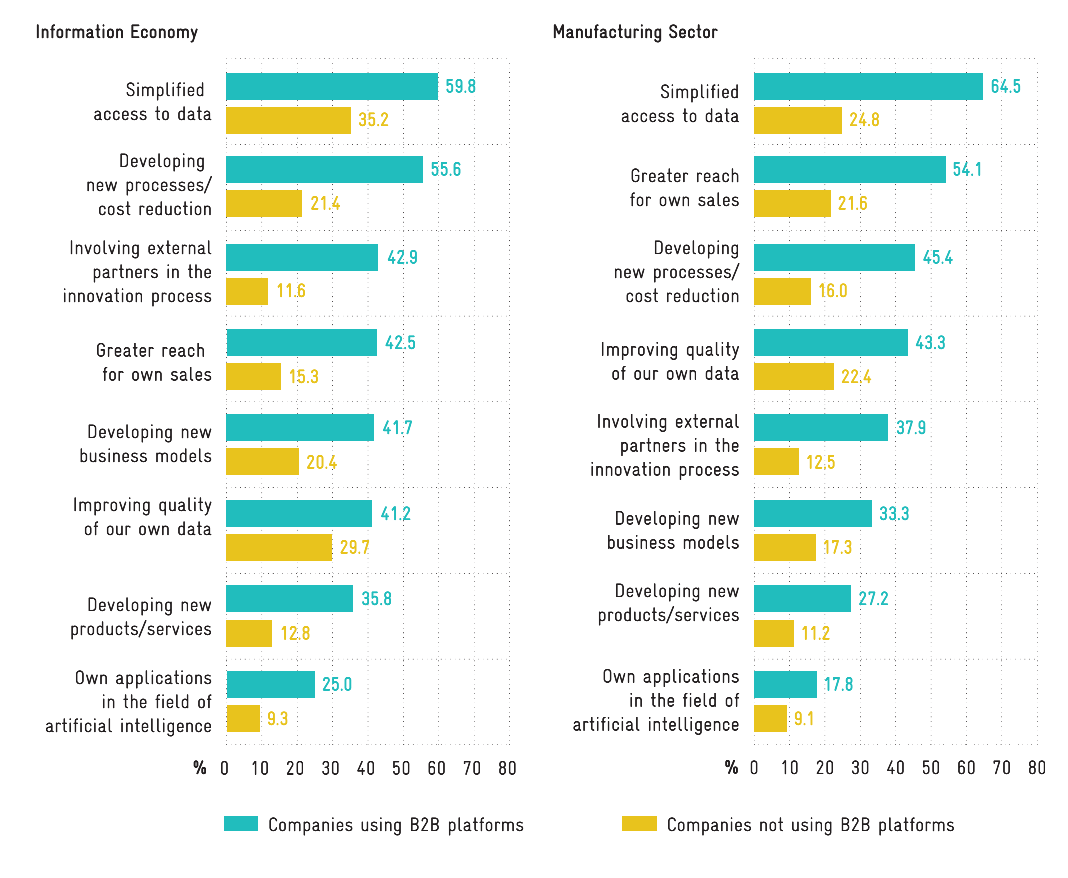
Fig. B 3-3 Impact of using digital B2B platforms on companies



Sector-specific extrapolation of the results to the question: 'What impact on your company could the use of digital B2B platforms potentially have/has the use had so far?' Multiple answers possible. Legend: 64.5 percent of manufacturing companies that already use B2B platforms see a positive impact from simplified access to data in their previous use of digital B2B platforms.
Source: ZEW Business Survey in the Information Economy (ZEW Konjunkturumfrage), 3rd quarter 2021.

development of new processes or cost reductions and the involvement of external partners in the innovation process follow in second and third place. In the manufacturing sector, the greater reach for own sales and the development of new processes or cost reductions take these positions among the platform-using companies.

A survey of around 1,260 companies in the German manufacturing sector from 2018 and 2019 also indicates a positive correlation between the use of IoT platforms and the turnover generated with product innovations. Manufacturing firms that use IoT platforms have an average of 6 percentage points higher turnover with product innovations than firms without IoT platform use.[310]

High Importance of Data for Platform-based Business Models

Although companies rate simplified access to data as the most important advantage in using B2B platforms, they have reservations about sharing their data with others because they expect it to worsen their competitive situation.[311] However, from an overall economic perspective, sharing data between companies would bring benefits.[312] Sharing data with other companies that use it to improve their services or processes, or making it available to start-ups that use it to train newly developed algorithms, can positively impact innovation activities.[313] Linking different data sets into data pools can also bring benefits, especially if the information in the merged data sets is complementary.[314] This is the case, for example, when data are merged and analyzed vertically along

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Fig. B 3-4 Risks for companies using digital B2B platforms

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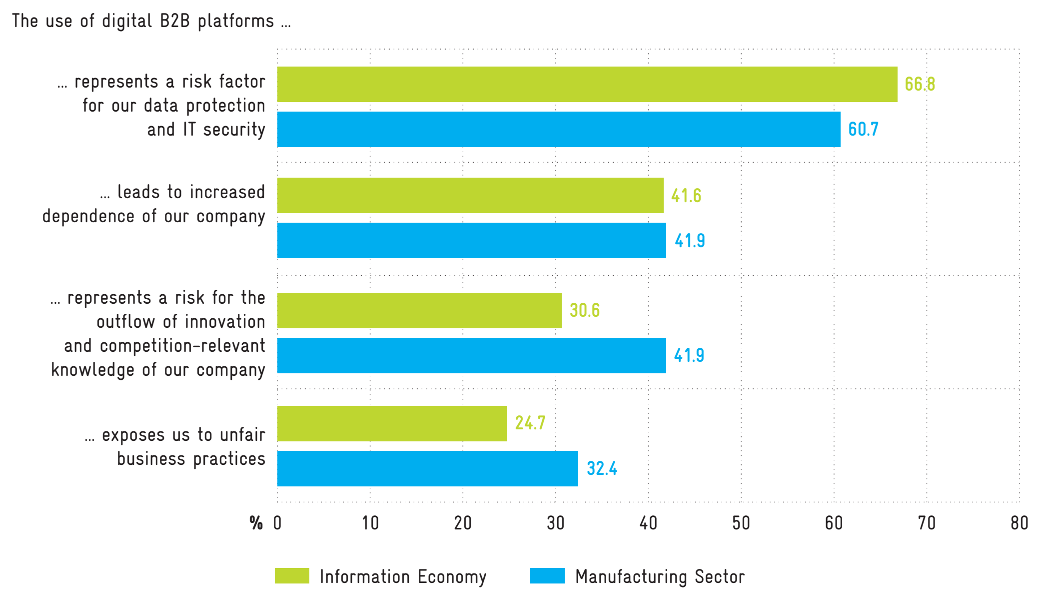

Sector-specific extrapolation of the results to the question: 'What risks for your company do you associate with the potential or actual use of digital B2B platforms? The use ...' Multiple answers possible. Legend: 60.7 percent of manufacturing companies say that the use of B2B digital platforms is a risk factor for their data protection and IT security.
Source: ZEW Business Survey in the Information Economy (ZEW Konjunkturumfrage), 3rd quarter 2021.

Box B 3-5 GAIA-X and Catena-X

The GAIA-X project, initiated by the then Federal Ministry for Economic Affairs and Energy in October 2019, is a European platform ecosystem consisting of various platforms. GAIA-X ensures uniform technical interfaces and standards for data protection and IT security,[315] based on which actors can exchange data securely and network internationally.[316] GAIA-X thus addresses the concerns of many German companies that see the use of a digital platform as a risk to their data protection and IT security (see figure B 3-4).

GAIA-X is not an independent cloud provider. Rather, GAIA-X offers the technical prerequisites to ensure data interoperability and to be a place for networking for companies, research institutions and initiatives. One application example of GAIA-X is the Catena-X Automotive Network (Catena-X).[317] Catena-X is a network consisting of companies in the automotive industry that work together in cloud-based data spaces. Data spaces are shared and trusted transaction spaces through which data are provided and shared in a decentralized manner, e.g. by companies or public administration. Standards for the technical infrastructure used for data exchange and collective data usage rules are intended to ensure trust in data spaces.[318] The aim of the data spaces within the framework of Catena-X is to share data collaboratively and openly along the automotive supply chain in order to develop innovative business processes and service products on this basis.

The initiators of GAIA-X have launched funding projects to establish further specific data spaces, e.g. for the areas of health, mobility and education, based on the GAIA-X infrastructure, and to develop them in the long term.[319] These data spaces should be designed as openly as possible to also enable data exchange across area boundaries.

Initiatives such as GAIA-X and Catena-X represent possible solutions for reducing companies' security concerns when sharing data and increasing their willingness to share their data with others. In addition, European and German platform solutions are intended to create more independence from existing US or Chinese cloud providers.[320]

value chains. This enables efficiency gains through better control of processes or the development of complementary products and services.

B 3-3 Challenges for Companies

For companies, the use of B2B platforms not only has positive effects but is also associated with various risks. In the representative survey conducted for the Commission of Experts, around 67 percent of companies in the information economy and 61 percent of companies in the manufacturing sector refer to risks to data protection and IT security (see figure B 3-4).[321] Another concern expressed by 42 percent of companies in the manufacturing sector and 31 percent of companies in the information economy is the outflow of knowledge relevant to innovation and competition. These findings point to the vital importance of mutual trust between platform actors.[322] The joint operation of a B2B platform could solve the trust problem of companies in platform use.[323] In so-called community platforms, companies are platform operators and users at the same time. The platform members jointly decide on governance structures, the design of algorithms as well as data usage rules and can adapt these to their individual needs. One project that is intended to support platforms in addressing these aspects and could promote the development of community platforms is GAIA-X (see box B 3-5).

According to the assessment of 42 percent of companies each in the information economy and the manufacturing sector, an increased dependence of the company on the platform also poses a risk when using digital B2B platforms. A lack of standards and compatibility as well as a lack of interoperability between platforms encourage such dependency. They are cited in various studies as further barriers to the use of B2B platforms.[324]

Small and medium-sized enterprises (SMEs) face particular challenges when using B2B platforms, especially technically complex IoT platforms. This is reflected in a low usage rate. The use of B2B platforms, especially in the industrial sector, requires high investments in building the necessary IT infrastructure. SMEs often do not have the financial resources and digital maturity required for this. In addition, there is a lack of (IT) specialists and know-how as well as awareness of the potential of platform use.[325]

Companies rate various possible measures by the Federal Government in relation to B2B platforms as conducive to innovation (see figure B 3-6). More than half of the companies in the information economy and manufacturing sector state that their innovation activities would benefit from clear liability rules in the event of data misuse, the provision of secure cloud infrastructures and the promotion of digital skills for handling data and platforms. Furthermore, a quality-based certification of (secure) platforms and the avoidance of a dominant position of platform operators would benefit the innovation activities of companies. A slightly smaller proportion of companies expect positive effects on their own innovation activities through the development of new concepts for data sharing and the promotion of anonymization procedures for data.

Regarding the measures mentioned, politics has already taken some initiatives. These include, for example, the European Commission's proposal for a law on digital markets, which is intended to ensure more competition among platform operators (cf. B 3-4). The European Data Strategy adopted in early 2020 aims to promote data sharing and make it more secure by creating clear rules for access and use. Ensuring secure data sharing by providing secure cloud infrastructures is the goal of the GAIA-X project launched in 2019 (see box B 3-5). The go-data module, newly launched by the Federal Government as part of the go-digital funding guideline, supports advisory services on data literacy.[326]

B 3-4 Regulation of Digital Platforms

Recently, numerous legislative projects and reforms have been passed or launched worldwide to adapt the existing regulatory framework to the challenges of the digital economy and to intensify competition in digital markets.[327] The regulations are geared towards the large platform operators, which have achieved very strong market positions through network effects and economies of scale. They apply in both B2B and B2C contexts. In addition to direct competition law regulations, questions of data access are also addressed.

Effects of Competition Law Measures on Innovation Activities Unclear

Germany adopted the tenth amendment to its national Act Against Restraints of Competition (Gesetz gegen Wettbewerbsbeschränkungen, GWB) in January 2021, giving the Federal Cartel Office (Bundeskartellamt) broader powers to regulate digital platforms.[328] The main innovation of the so-called GWB Digitalization Act is the introduction of a regulation enabling the Federal Cartel Office to determine that a company which is active to a significant extent on platform markets has a paramount significance across markets with potentially anti-competitive consequences (Section 19a GWB).[329] If this is the case, the Federal Cartel Office can impose ex-ante prohibitions on the company, i.e. without having to prove abuse. For example, the preferential treatment of own services can be prohibited. Likewise, the processing of competition-relevant data collected by the company to erect or appreciably raise barriers to market entry can be prevented. This also applies to competition-relevant data received from other companies if these are processed for purposes other than those necessary for the provision of the provider's own services to these companies without offering these companies a sufficient choice. Prohibitions can also concern the obstruction of interoperability between products or services and data portability.[330] Certain conducts can be exempted from the prohibition if the company can objectively justify it. In January of this year, the Federal Cartel Office issued the first decision based on Section 19a of the GWB, finding Google to be of paramount significance across markets.[331]

Fig. B 3-6 Possible measures by the Federal Government regarding B2B platforms that would benefit the innovation activity of companies

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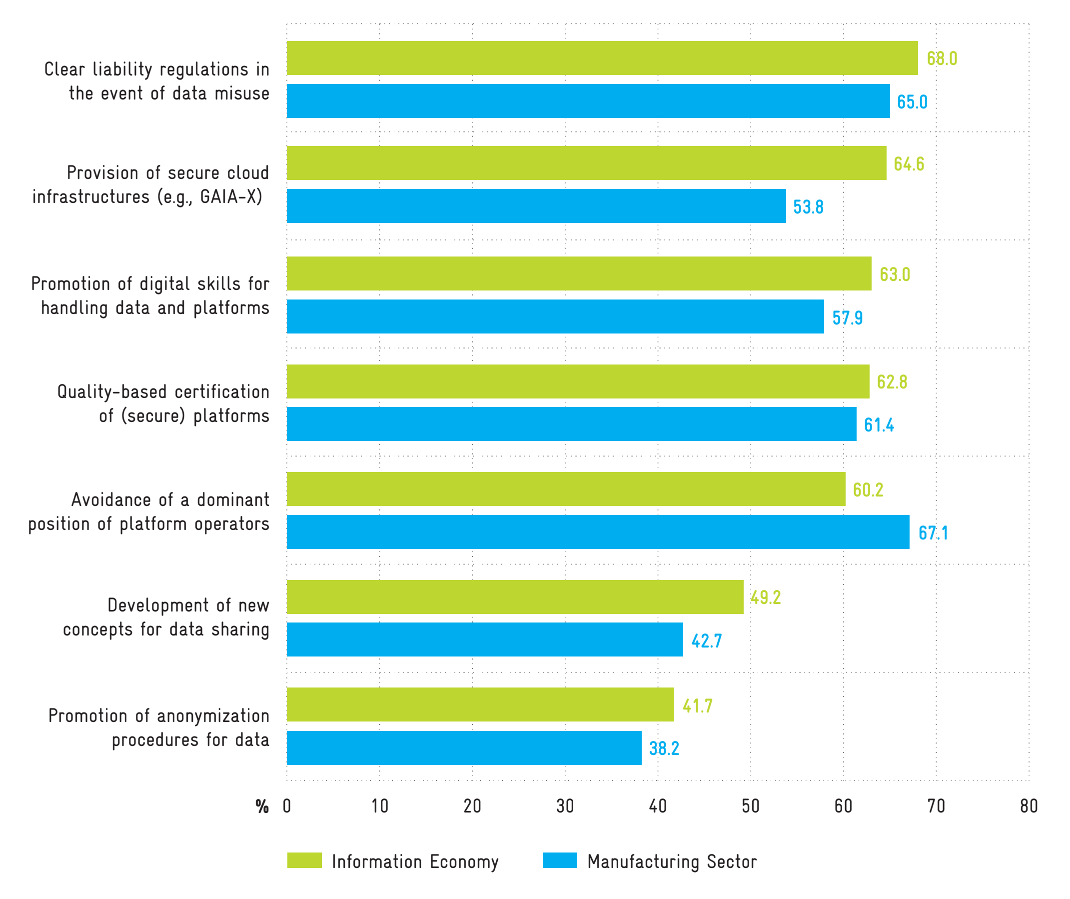


Sector-specific extrapolation of the results to the question: 'Which of the Federal Government's measures would benefit your company's innovation activities?' Multiple answers possible. Legend: 65.0 percent of manufacturing companies state that their innovation activities would benefit from clear liability rules in the event of data misuse.
Source: ZEW Business Survey in the Information Economy (ZEW Konjunkturumfrage), 3rd quarter 2021.

Further amendments to the GWB Digitalization Act concern, among other things, the identification of a market dominating position. Thus, when assessing the market position of a platform, its intermediation power, i. e. the importance of the intermediation services it provides for access to procurement and sales markets, as well as its access to competition-relevant data must be considered.[332] In addition, data access for third parties is simplified in principle by the GWB Digitalization Act. On the one hand, because data are defined as an essential facility. On the other hand, because dependency can arise from the fact that a company is dependent on access to data controlled by another company for its own activities, and this dependency is considered a relevant competitive concern.[333] The Commission of Experts welcomes this facilitation of access to data, as it can provide positive impulses for innovation.

The proposal for a regulation on contestable and fair markets in the digital sector (Digital Markets Act, DMA)[334] published by the European Commission in December 2020 aims to promote competition between platforms and to ensure fair behaviour by platform operators towards their users.[335] The DMA is intended to impose obligations on large dominant platforms, so-called gatekeepers,[336] which are largely derived from abusive behaviour by platform operators in previous competition cases.[337] Among other things, gatekeepers are prohibited ex-ante from using non-publicly accessible data generated by the activities of commercial users in competition with said commercial users, and from favouring their own products and services on their platform in rankings over those of other providers. In addition, gatekeepers will be required to enable data portability and interoperability.[338] Based on market research, the European Commission may dynamically adjust the list of obligations.[339] If a gatekeeper fails to comply with the obligations, the European Commission may impose a fine of up to 10 percent of its total turnover in the preceding business year.[340] In the case of systematic violations, it may also impose behavioural or structural remedies on gatekeepers, up to and including breaking up the corporation.[341]

The draft law is currently in the ordinary legislative procedure of the European Union (EU), in the context of which the European Parliament adopted its position on the DMA on 15 December 2021.[342] In the parliamentary draft, among other things, the thresholds for annual turnover and market capitalization above which companies are classified as gatekeepers were raised,[343] the fines for non-compliance with the rules of conduct were increased, and selected rules of conduct, such as on interoperability or on default settings, were tightened.[344]

In principle, the Commission of Experts welcomes the fact that the GWB Digitalization Act and the DMA, which is currently being voted on, are intended to intensify competition on digital markets and improve access to data, as this can provide impetus for the innovation activities of companies in the platform economy. Companies that are active as providers on the large platforms could, for example, use the data resulting from the platform activity and made available to them on a mandatory basis to develop products or services that are complementary to platform offerings.[345] In addition, barriers to market entry are reduced and competition between platform operators is promoted. Platform operators should consequently have more incentives to invest in research and innovation and to further improve the quality of their products and services. At the same time, market entry for new providers will be facilitated.

However, the prohibitions in the already applicable GWB Digitalization Act and the behavioural requirements for large platform operators provided for in the DMA may also reduce their incentives to innovate. Restrictions on the platform operators' room for manoeuvre, for example in the exploitation of data, could lead to a lack of innovation.[346] To maintain incentives for innovation on the part of platform operators, the DMA, like the GWB Digitalization Act, should also provide for exceptions to the rules of conduct in justified individual cases.[347] In order not to jeopardize rapid enforcement, the gatekeeper should be bound by the rules of conduct until it has objectively justified the respective conduct.

While the GWB Digitalization Act did not introduce stricter rules for company takeovers by platform operators, gatekeepers are obliged under the planned DMA to inform the European Commission of any takeover attempts in the digital sector.[348] In cases of systematic non-compliance with the behavioural requirements, the parliamentary draft even provides for the European Commission to be empowered to prohibit relevant takeovers by gatekeepers for a limited period of time.[349] The Commission of Experts considers stricter requirements for company takeovers by platform operators to be sensible, as overall there is much to suggest that too much market concentration can have an inhibiting effect on innovation.[350]

The differences between the regulatory frameworks formulated in the GWB Digitalization Act and in the proposed DMA may lead to legal uncertainty for companies and thus hinder the emergence and dissemination of innovative digital business models.[351] This may counteract the positive impulses that these regulations may have on innovation activities in the platform economy, at least in the initial phase of their implementation.

Promotion of Data Access and Use Initiated

In addition to competition law measures, numerous regulations have also been adopted or launched recently to promote the provision of data and facilitate data sharing by creating clear rules.[352] This can help to better exploit the potential of data-driven innovation.

For example, the recast of the European Directive on open data and the re-use of public sector information (Open Data Directive), which came into force in June 2019, aims to increase the availability of public sector data by introducing Europe-wide minimum rules for the re-use of such data.[353] This will improve the conditions for creating data spaces on platforms.

To increase trust in data sharing and reduce transaction costs for companies when sharing data, the Data Governance Act (DGA) presented in November 2020, the first of several announced legislative proposals within the European Data Strategy, aims to create uniform rules for data sharing across Europe. At the end of 2021, the Council of the EU and the European Parliament reached a preliminary agreement on the draft law. In particular, the DGA defines conditions for data intermediaries, i. e. providers of data-sharing services, and thus lays a legal foundation for data trustee models.[354] Such services may include, for example, the establishment of platforms (data marketplaces) to enable the exchange or joint exploitation of data and the establishment of the technical infrastructure for the networking of data holders and users. According to the DGA, data intermediaries must, above all, remain neutral with regard to the exchanged data and may not use the data for other purposes.[355]

Another key legislative project of the European Data Strategy is the Data Act, which builds on the planned Data Governance Act and for which the European Commission published its impact assessment at the end of May 2021.[356] The planned introduction of (sector-)specific data access and usage rights is likely to be of particular importance for the B2B sector. Data transmission and sharing between companies as well as between companies and the public sector are also to be simplified and accelerated. To this end, the Data Act provides for the establishment of harmonized contractual standards for data sharing. In addition, the creation of sector-specific European Data Spaces is an important objective of the European Data Strategy.[357]

Legal Certainty in Horizontal Cooperation Agreements on Data Use Insufficient

The development and growth of B2B platforms are also likely to be influenced by the revision of antitrust regulations. Horizontal cooperation agreements between companies can serve, among other things, to share risks, save costs, share data, pool know-how and accelerate innovation.[358] However, they can also have coordinating effects regarding so-called hardcore restrictions[359] such as price fixing and companies can thus violate antitrust law.[360]

Existing European regulations that are intended to provide legal certainty to companies in their self-assessment regarding antitrust limits of horizontal business cooperation or exempt horizontal business cooperation from the ban on cartels under certain conditions expire at the end of 2022. To decide on further reforms, the European Commission conducted consultations in 2021 to evaluate and revise the regulations. Among other things, it was determined that the Horizontal Guidelines for the self-review of data exchange and data pooling agreements do not provide sufficient legal certainty.[361] The tenth GWB amendment opens the possibility for companies to have an antitrust assessment of cooperations carried out by the Federal Cartel Office if there is a substantial legal and economic interest in this decision. With a so-called chairman's letter, the Federal Cartel Office can informally allow cooperations.[362] It is not yet foreseeable how this new regulation will change horizontal cooperations and innovation activities in the B2B platform economy.

The legal measures for the regulation of digital platforms that have already been passed and those that are still being voted on aim to intensify competition and provide incentives for innovation. However, the multitude and dynamics of legal measures at different levels lead to legal uncertainty for companies and could thus impair innovation activities. Regulations on interoperability and data portability can set both positive and negative incentives for innovation. Therefore, it is crucial to evaluate the impact of new legal measures and regulations on the innovation activities of the actors in the platform ecosystem.

B 3-5 Recommendations for Action

Digital platforms orchestrate the interaction of different stakeholder groups and enable the development of innovative business models as well as new products and services. Data are a key value-creation factor in this context. B2B platforms, especially data-based platforms, open up great potential, as they can be used to achieve efficiency gains in production and enable innovations. It is important to leverage the potential associated with B2B platforms and to avoid a drain of value creation from German companies to the large B2C platforms from the USA and China that are increasingly penetrating the B2B sector. The Commission of Experts therefore recommends:

Promoting Open Data

— The requirements of the Open Data Directive and measures of the Open Data Strategy should be implemented quickly and consistently so that public administrative and research data can also be better used for innovation.

Expediting the Development of European Data Spaces

— Building a high-performance, competitive, secure and trustworthy data infrastructure for Europe is a prerequisite for the successful development of the B2B platform economy. GAIA-X can play an important role in this and should therefore be implemented consistently.

— The success of GAIA-X depends on how well and how quickly it succeeds in establishing ecosystems for data sharing and developing applications for data use in addition to the planned data spaces. Suitable governance structures must be established for this purpose.

— To contribute to the acceptance and success of the project, the Federal Government should improve the conditions for the public sector to be able to provide its own data and services on the GAIA-X infrastructure as a pioneer.

— The Federal Government is requested to review the progress of GAIA-X in a timely manner and at regular intervals. If it becomes apparent that GAIA-X is falling significantly and permanently short of the targets set, funding should be adjusted accordingly.

Setting Incentives for Data Sharing

— The Commission of Experts welcomes the measures planned in the draft European Data Governance Act, especially the introduction of data intermediaries. However, it recommends designing the framework conditions for data intermediaries in such a way that stakeholders have an incentive to offer such intermediary services and high-quality services are ensured.

— In the reform of the European Horizontal Guidelines and the associated regulations, which exempt horizontal business cooperation from the ban on cartels under certain conditions, care should be taken to reduce as far as possible the uncertainty on the part of companies regarding horizontal cooperations for exchange of data regarding the assessment under cartel law.[363]

— To increase trust in B2B platform ecosystems, the creation of B2B platforms that companies operate and design collaboratively should be encouraged.

Supporting SMEs in the Use of B2B Platforms

— Low-threshold information and advisory services are particularly important for SMEs. The existing initiatives to promote the use of digital B2B platforms, such as the services of the Mittelstand 4.0 competence centres, should be continued and expanded.

- Data literacy training should be further reinforced. Against this background, the Commission of Experts welcomes the extension of the go-digital support programme until the end of 2024 and in particular the newly included go-data module, which supports advisory services to improve data literacy in SMEs.

Check Implementation of Data Portability and Interoperability

- Since improved data portability and interoperability of digital platforms facilitate the simultaneous use of several platforms and thus favour competition and innovation, the Commission of Experts supports the regulations provided for in the GWB Digitalization Act and the DMA. However, it urges that suitable criteria must be developed in order to be able to check the implementation of data portability and interoperability.

Expediting EU-wide Uniform Platform Regulation

- The further development of the digital single market through an EU-wide uniform regulatory framework improves the scalability of platform- and data-based B2B business models. Therefore, the Federal Government and the European Commission should advocate for an EU-wide uniform platform regulation.

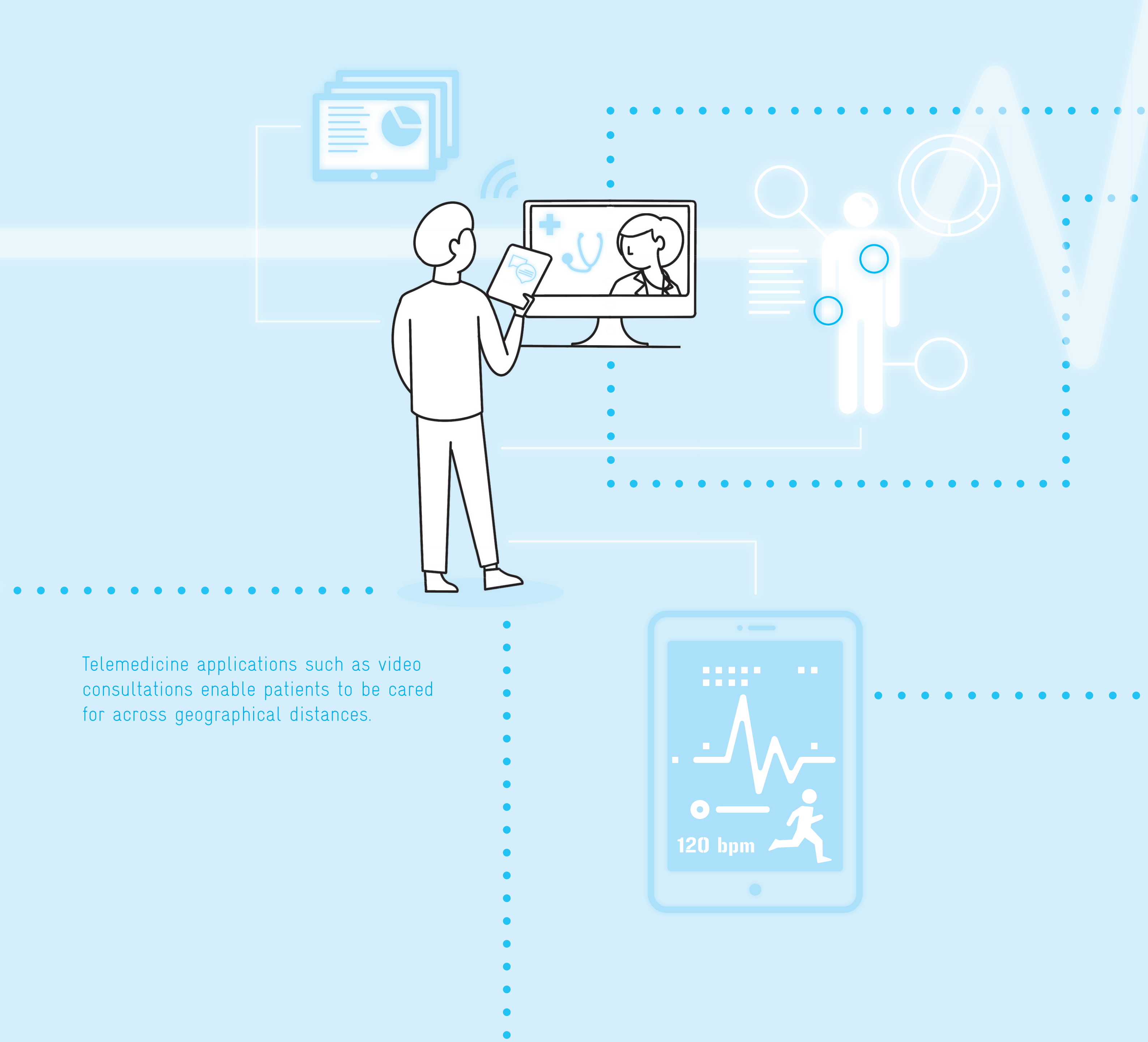
Evaluating the Innovation Effects of New Competition Law Regulations

- Currently, the effects of regulatory measures such as the tenth GWB amendment and the DMA, currently in the voting process, on innovation activities in platform ecosystems cannot be foreseen.It is therefore necessary to evaluate the measures for their innovation effects after their introduction. The emergence of similarly high market concentrations as in the B2C sector should be prevented.

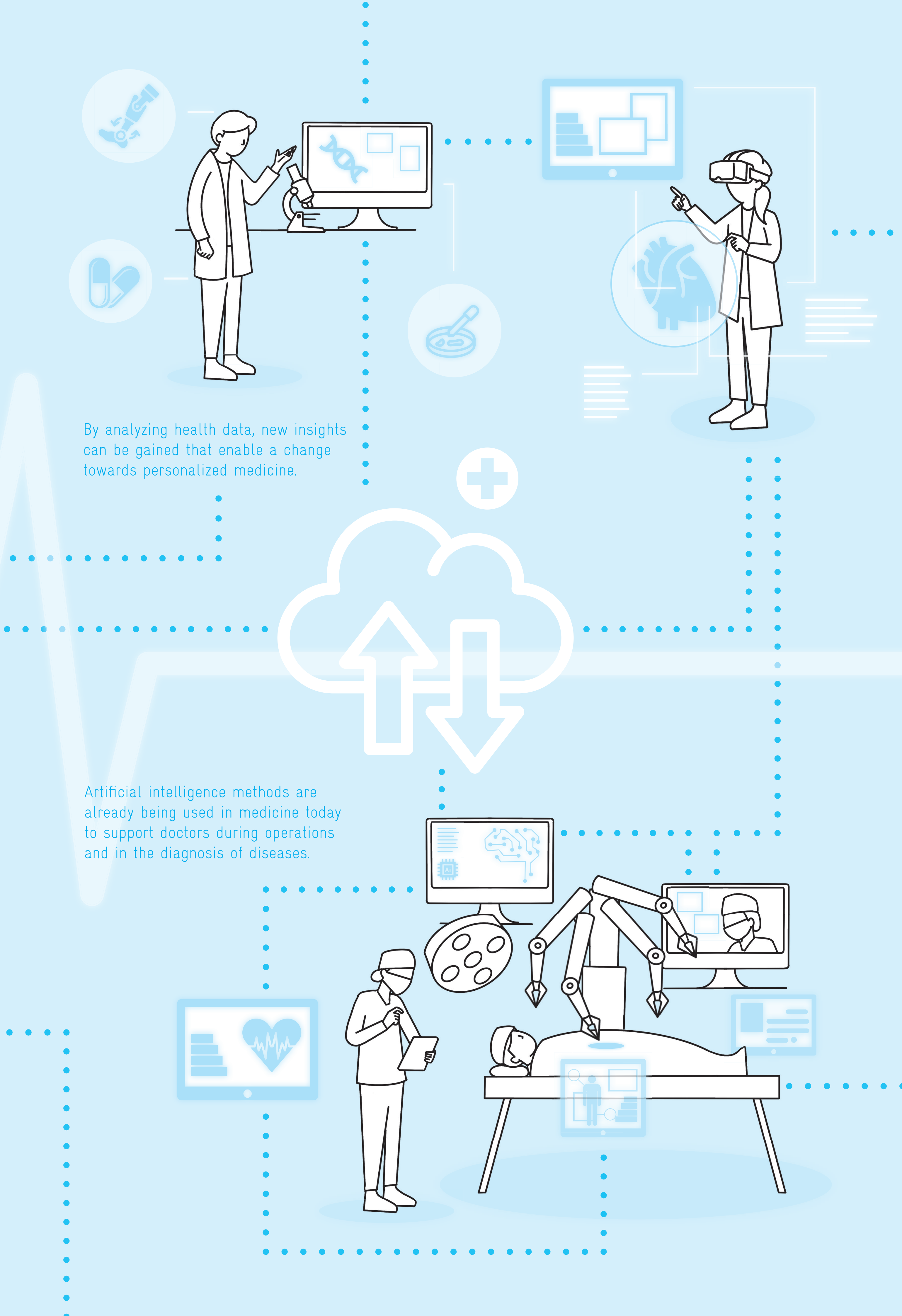
B 4 Digital Transformation in the Healthcare System

Download Data

The digitalization of the healthcare system is associated with great potential for innovation and value creation with regard to better quality and more efficient healthcare. In particular, the increasing availability of health data in combination with new digital analysis methods opens up opportunities for more personalized diagnostics and treatment.



Telemedicine applications such as video consultations enable patients to be cared for across geographical distances.



By analyzing health data, new insights can be gained that enable a change towards personalized medicine.

Artificial intelligence methods are already being used in medicine today to support doctors during operations and in the diagnosis of diseases.

B 4 Digital Transformation in the Healthcare System

The digitalization in the healthcare system is associated with great potential for innovation and value creation.[364] In administration as well as in treatment and care, digital technologies can increase the efficiency of service provision through renewed and optimized processes and thus improve the allocation of resources.[365] In addition, the application of digital technologies and the use of health data can contribute to significantly increasing the quality of healthcare, for example by improving individual diagnostics and developing innovative treatments.

International comparative studies show that Germany lags far behind other European countries in the digitalization of the healthcare system.[366] For example, in recent benchmarking studies Germany mostly only ranks in the bottom third.[367] One example of the slow implementation of digitalization in the healthcare system is the failed introduction of electronic prescriptions (e-prescriptions). Despite a 16-year planning and preparation phase, it was not possible to bring this into use on 1 January 2022 as planned. Further massive deficits in the digitalization of the healthcare sector were revealed during the COVID-19 pandemic.[368]

Against the background of these deficits, this chapter is dedicated to the question of how the implementation of the digital transformation in the healthcare system can be advanced and the associated innovation potentials can be unlocked. To this end, starting from an inventory of the framework conditions and measures already implemented, the view is successively broadened and directed towards future potentials and innovations in the healthcare system.

B 4-1 Stakeholders, Legal Regulations and Elements of the Digital Transformation

Legal regulations provide the framework to be able to leverage the potential associated with the digitalization of the healthcare system and to improve healthcare. The technical basis for the digital transformation of the healthcare system is the so-called telematics infrastructure (TI), which networks the stakeholders in the healthcare system and enables the secure, cross-organisational exchange of information and data. The electronic patient record (ePR), which bundles the health data of patients, is the most important TI application. In addition, health apps such as digital health applications (Digitale Gesundheitsanwendung, DiGA) and telemedical applications such as video consultations are key elements of the digital transformation of the healthcare system.

Stakeholders in the Health System and Legal Regulations as a Framework for Digital Transformation

The stakeholder landscape in the German healthcare system is complex and heterogeneous. There is a multitude of stakeholders with distributed responsibilities and competences resulting from the principle of self-administration. In addition to service providers such as doctors, psychotherapists and other members of the healing and nursing professions, patients, too, are stakeholders in the healthcare system. Others include hospitals, pharmacies and care facilities, the statutory health insurance funds (Gesetzliche Krankenkassen, GKV) and private insurance providers, as well as science, the economy, numerous interest groups and politics.[369]

While the Federal Government has the task of defining the legal framework for the healthcare system and its stakeholders, the Länder are responsible for outpatient and inpatient care. Finally, the service providers as well as the insurers in their capacity as payers are responsible for the execution of medical care and the billing of services.[370]

The first legal regulations for the modernization and digitalization of the healthcare system were addressed in Germany as early as 2003 with the Act on the Modernization of the Statutory Health Insurance Funds (GKV Modernization Act).[371, 372] Among other things, the creation of an information, communication and security infrastructure, the later TI, as well as the introduction of the ePR were decided in this act.[373] However, the implementation of the measures provided for in the act was slow in the following decade.

To accelerate the processes of digitalization, the E-Health Act was first passed in 2015, setting specific deadlines for the introduction of the TI and the ePR. Finally, further laws were passed in the past legislative period to accelerate the digital transformation of the healthcare system. For example, with the Appointment Service and Care Act passed in 2019, the statutory health insurance funds were obliged, among other things, to provide all statutorily insured persons with an ePR by 1 January 2021.[374] The Digital Care Act, which also came into force in 2019, aims to improve care through digitalization and innovation.[375] In it, the possibility was created to prescribe digital health applications (DiGAs) and to bill their use via the statutory health insurance funds.[376] In addition, the Act facilitated the provision of telemedical services such as video consultations.[377] The Patient Data Protection Act, passed in 2020, provided, among other things, for the mandatory use of the e-prescription as of 1 January 2022, as well as the possibility for statutorily insured persons to release their ePR data for research purposes.[378]

Telematics Infrastructure (TI) as the Backbone of the Digitalization of the Healthcare System

A digital infrastructure that connects all stakeholders in the healthcare system and enables secure, cross-organizational exchange of information and data is the basis for successful digitalization. In Germany, the so-called telematics infrastructure (TI) fulfils these tasks. It consists of decentralized components[379] such as card readers as well as centralized hardware and software components, including the secure e-mail service Kommunikation im Medizinwesen (KIM).[380] These components and services provide the technical platform for networking stakeholders and for offering specialized applications such as the ePR and e-prescription.[381]

Gematik was founded in 2005 as a joint initiative of the umbrella organizations in the healthcare sector for the conceptual preparation and establishment of the TI.[382] Furthermore, the E-Health Act set mandatory deadlines for medical service providers to connect to the TI by 31 August 2018.[383] However, conflicting stakeholder interests in gematik's shareholders' meeting in conjunction with the required two-thirds majority for decisions prevented the connection of medical service providers by the set deadlines. Therefore, a restructuring was carried out within the framework of the Appointment Service and Care Act and the Federal Ministry of Health took over 51 percent of gematik's shares, making it its main shareholder. In addition, it was determined that decisions in the shareholders' meeting could be made by simple majority.

In addition to the conception and establishment of the TI, gematik's tasks also include the operational coordination and further development of the TI and associated specialist applications.[384] To ensure the functionality and security of the TI, gematik specifies functional and technical requirements for components, technical services and providers of operational services, thus setting standards for the digital healthcare system. It is also responsible for the approval of components, services and providers in the TI. Furthermore, gematik has the task of monitoring new technological developments and taking them into account in the expansion of the TI. In this context, a redesign towards TI 2.0 took place in 2021.[385] This aims in particular to create added value beyond the digitalization of analogue data through the user-friendly and secure networking of stakeholders and the use of data.[386]

Based on the Health IT Interoperability Governance Regulation, which came into force on 15 October 2021, gematik coordinates interoperability and thus promotes frictionless and efficient data transfer between the stakeholders in the German healthcare system.[387]

The reform of gematik has helped to overcome blockades that delayed and hindered the establishment of the TI for years. In the coming years, it will be important to rapidly expand the TI and further develop it in line with changing needs.

Electronic Patient Record (ePR) as a Core Element of Digital Healthcare

An ePR records the most important health-related information of insured persons in a digital documentation system and makes this information available to service providers across disciplines, institutions and sectors. It is a core element of a digitalized healthcare system.[388]

Through immediate and location-independent access to structured information, an ePR can enable more needs-based and better coordinated care. For example, it can improve compliance with medical prescriptions through integrated medication intake management.[389] In addition, the use of an ePR can also contribute to greater cost-effectiveness in healthcare.[390] For example, a meta-analysis from the USA concludes that hospitals that use an ePR with basic functions have 12 percent lower average costs than hospitals that do not use an ePR. The study attributes the savings primarily to the reduction of medication errors, more efficient organizational processes and shorter hospital stays.[391] Finally, the use of ePR data for research purposes can help to diagnose diseases earlier and find more appropriate treatments.[392]

The introduction of ePR was already planned in Germany as part of the GKV Modernization Act in 2003. However, the self-administration stakeholders failed in implementing the ePR in the following years. It was not until the laws on the digitalization of the healthcare system passed in the 2017 to 2021 legislative period that a concrete roadmap for the introduction of the ePR was established.[393]

As part of the first expansion phase since January 2021, statutorily insured persons were enabled to use an ePR provided by their health insurance fund. This enabled the first documents such as the emergency data record,[394] the medication plan and doctors' letters to be stored in the ePR. The second expansion phase, which came into force in January 2022, provides for statutorily insured persons to be able to access their vaccination certificate digitally, among other things. In the third expansion phase, which is planned to start in January 2023, people with statutory health insurance are to be given the option of releasing their data stored on the ePR pseudonymized for research purposes.[395]

The use of the ePR has so far been on a voluntary basis. By the end of 2021, only 312,000 of the approximately 73 million statutorily insured persons in Germany had opted for this.[396] For the establishment of the ePR and the allocation of data processing rights, the Patient Data Protection Act (Patientendaten-Schutzgesetz) currently provides for a multi-stage consent procedure (opt-in procedure[397]) by the insured persons. Users must give the respective treating health care providers access to their ePR data by consent, whereby the consent must be given separately for each health care provider involved in the treatment.[398] This cumbersome consent procedure as well as the lack of awareness of the ePR contribute to the fact that only a few insured persons decide to set up the ePR and that it is therefore not used nationwide, as was also the case in France (see box B 4-1). The Commission of Experts therefore considers the introduction of an opt-out procedure[399] planned in the coalition agreement to be a purposeful adjustment. In addition, the statutory health insurance funds should demonstrate to the insured the added value of using the ePR for better care by means of useful applications, such as the electronic storage of the medication plan.

Telemedicine Applications as a Complement to Care

In addition to medical care over spatial and temporal (asynchronous) distances,[400] telemedicine also includes general care concepts for the provision of medical services with the help of information and communication technologies.[401] Despite the great potential of medical video consultations for improved healthcare, the use of corresponding services remained at a low level for a long time. From March to December 2019, for example, around 2,800 video consultations were carried out throughout Germany. Largely influenced by the COVID-19 pandemic and some regulatory simplifications, this number rose to over 2.5 million in the same period of the following year.[402]

Telemedicine applications can have a positive impact on healthcare.[403] On the one hand, they can help to improve the general health status of patients. On the other hand, they can save time and costs for the service providers.[404] Particularly against the background of the current and increasing shortage of doctors in rural regions, telemedical applications are associated with great potential for ensuring care.[405] However, according to studies, citizens in rural areas tend to have a lower acceptance of telemedical services than citizens in urban areas.[406] In addition, older people use telemedical health services to a lesser extent than younger people.[407]

To increase the use of approved and therapeutically useful telemedicine options, the service providers, especially the physicians in private practice, play an important role. They need sufficient financial incentives to opt for this form of treatment. At present, services provided by telemedicine are generally charged at the same rates as conventionally provided services, but in some cases at lower rates.[411] Grants and subsidies are available for the additional expenditure required in the introductory phase – for the acquisition of software and hardware, further training, additional information and education of patients.[412] Such subsidies for the initial investment costs of service providers appear to make sense in view of the dynamic efficiency gains associated with the widespread use of telemedicine. Against this background, it also seems reasonable in an initial phase to remunerate services provided by telemedicine with the same fees as comparable services provided conventionally. Once telemedicine has become established, the efficiency gains for service providers should be distributed appropriately between them and the insured, and cost rates should be adjusted accordingly, i. e. reduced.

Box B 4-1 The Austrian Electronic Health Record and the French Dossier Médical Partagé

In Austria, the electronic health record ELGA, which enables access to health data by service providers across disciplines and institutions, has been gradually introduced since 2015.[408] As part of the introduction of ELGA, the Electronic Health Record Act created the legal basis for an opt-out regulation. According to this, an ELGA is initially created for all citizens, but they can opt out at any time via the ELGA objection centre. In June 2021, just under 97 percent of citizens in Austria had an ELGA, which is also being used accordingly: as of October 2021, 89 percent of all laboratory results and 91 percent of medical discharge letters were recorded in a structured, exchangeable and machine-readable form.[409]

The establishment of the French ePR (Dossier Médical Partagé, DMP) has been very slow since its introduction in 2006. Of the nearly 40 million DMPs planned, only about 580,000 existed in 2016. The main reasons cited are the restrictive and complicated access management and the opt-in rule. After the reform in 2018 with various structural adjustments, such as the improvement of interoperability and stronger funding incentives for service providers, the use could be increased to eight million DMPs.[410]

Potential of Digital Health Applications

With the introduction of the DiGA (Digitale Gesundheitsanwendung – digital health application, or app) in October 2020, Germany is the first country where physicians and psychotherapists can prescribe ‘apps on prescription’.[413] DiGAs are certified medical devices whose main function is based on digital technologies and which are used to diagnose and treat diseases.[414] Unlike common health and fitness apps, the costs for DiGAs are reimbursed by the statutory health insurance funds.

A prerequisite for the prescription of a DiGA is its inclusion in the DiGA directory. For a DiGA to be included in the official DiGA directory by the Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte, BfArM), the developers must, among other things, state which positive healthcare effect the application achieves and provide evidence on data protection requirements. Within the framework of the fast-track approval procedure, which provides for an assessment period by the BfArM of a maximum of three months, there is also the possibility of a provisional inclusion in the DiGA directory for a maximum of one year, in addition to permanent inclusion.[415] A total of 20 of the 28 DiGAs currently approved for reimbursement in standard care have so far only been provisionally included in the directory. Most of the approved DiGAs are aimed at the treatment of mental illness.[416] According to the umbrella organization of occupational health insurance funds, at least 39,000 statutorily insured persons had used an application listed in the DiGA directory by the end of 2021.[417]

To achieve a faster reimbursement decision, the evidence required in the approval process for inclusion in the DiGA directory could be made more dependent on the risk of undesirable side effects and the degree of vulnerability of the target group.[418] Furthermore, the data generated during the prescription and use of DiGAs should be used by the statutory health insurance funds to evaluate them regularly with regard to their medical effectiveness. Developers should do this with a view on the technical functionality of the DiGAs.

Due to their direct relation to patients, the attitudes of healthcare providers towards app-based treatments are of significant importance for the dissemination of DiGAs. Studies show that most of the physicians and psychotherapists surveyed have a fundamentally positive attitude towards DiGA[419] and health apps[420] and recognize a clear added value for patients in their use. Nevertheless, the majority of respondents refer to existing uncertainties and a lack of information regarding the use of DiGAs, data security and medical evidence, which ultimately makes adequate advice and support for patients more difficult.

According to an arbitration procedure concluded in December 2021 to regulate maximum prices in the framework agreement between DiGA manufacturers and the National Association of Statutory Health Insurance Funds (GKV-Spitzenverband), reimbursement in the first year after inclusion in the DiGA directory will in future be made up to group-specific maximum prices.[421] These are based in particular on the respective indication group and are to be adjusted every six months if necessary. Exceptions to the reimbursement limit exist for applications that mainly address rare diseases or whose main function is based on artificial intelligence. Likewise, the first 2,000 prescriptions of an application are exempt from the maximum price. The long-term reimbursement amounts of the individual applications beyond the first twelve months are determined in negotiations between the National Association of Statutory Health Insurance Funds and the individual developers.

To link the amount of reimbursement more closely to the actual added value and the long-term use of the respective application, current considerations are also discussing use- or performance-based reimbursement models.[422] This could create even stronger incentives for high-quality products on the part of the developers and avoid an excessive cost burden on the statutory health insurance funds.

B 4-2 Use of Health and Healthcare Data for Research and Innovation

Data are essential for the further development of medical research, public health research[423] and healthcare. Especially through the development of new diagnostic and therapeutic options, they can contribute to significantly improving healthcare and supporting innovations in the healthcare industry, for example in the health tech sector (see box B 4-2).

Data are generated both in the medical research and development process and in the treatment of patients. Digitalization contributes to improving the availability of existing health data along the entire medical care chain and to generating new data on a large scale. The analysis of this data opens up innovation potential, especially in data-based medical research.

Potential of Data in the Healthcare Sector

Data that are explicitly collected for medical research purposes can help to gain new medical and therapeutic insights and enable their translation into application. For example, data from clinical trials provide information on the safety and efficacy of therapeutic agents. In addition, data from biobanks and clinical registries can be used to research the causes of diseases.[424]

Moreover, data from everyday care generated in connection with the treatment of patients can be used for research within the scope of secondary use.[425] For example, these data can be used in medical research to conduct comparative effectiveness studies as well as to track the course of treatments.[426] Care and billing data also make it possible to develop new concepts for healthcare within the scope of public health research. The comprehensive pooling of health data from care, which is made possible by an ePR, facilitates its use and holds great potential for improving health services.[427] For example, anonymized data have been used in the United Kingdom for over 30 years, among other things, to investigate questions of drug safety, drug use and the effectiveness of health policy measures.[428]

Through the comprehensive analysis of data with digital technologies, new insights can be gained in research that enable a change towards personalized medicine.[429] For example, data-driven medical research is based on the analysis of large amounts of data using high-performance computers. Particularly in the field of analyzing medical images, artificial intelligence methods are already well developed and are used, among other things, to help doctors diagnose diseases such as skin cancer.[430]

Genetic data have the potential to significantly advance disease research. For example, in the case of SARS-CoV-2, genome sequencing with digital high-throughput methods makes it possible to detect virus variants and their changes in terms of their transmission behaviour. The sequencing results can also be used to measure the severity of diseases caused by the SARS-CoV-2 variants and to take targeted measures.[431] The '1+ Million Genomes' initiative funded under Horizon 2020 aims to systematically bring together data from regional, national and international projects with strict regard to data protection and data security and to make them accessible for research.[432] By 2022, scientists in the EU should thus be able to access at least one

Box B 4-2 Health Tech Innovations

Between 2019 and 2021, the number of unicorns, i.e. start-ups with a market valuation of more than US$1 billion, doubled globally from 38 to 76.[433] The USA accounts for by far the most unicorns, with 51 (see figure B 4-3). Eight companies of this type are based in China and six in the EU, with Ottobock[434] and ATAI Life Sciences[435] two of them in Germany. The market valuation of all health tech unicorns is over US$160 billion, of which US-American unicorns account for about 75 percent. In addition to developing individual diagnoses and treatments using artificial intelligence, the companies operate in the areas of early detection and behaviour management, among others.[436] For example, Oxford Nanopore, a spin-off of Oxford University, is developing new sequencing technologies that can be used to diagnose cancer.[437] In the area of behaviour management, the app Noom uses the latest findings from behavioural research to empower people to improve their health and live healthier lives.[438]

Fig. B 4-3 Number of health tech unicorns by countries and regions 2021

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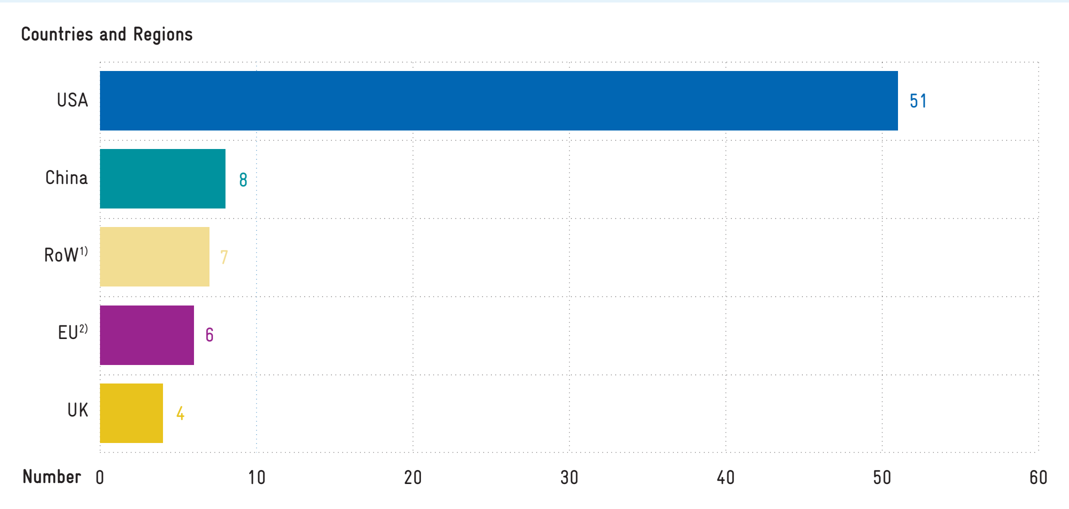


1) ROW = Rest of the World. Includes Switzerland and Israel with two unicorns each, and India, Canada and South Korea with one unicorn each.
2) Two unicorns each are based in Germany and France; Ireland and Sweden each account for one unicorn.
Source: Own representation based on data by www.holoniq.com/healthtech-unicorns/.

million genome sequences across countries. The volume of data enables researchers to gain new and more robust insights into the origins of diseases and to develop opportunities for new personalized diagnoses and treatments.

Interoperability, Infrastructure and Data Access

To ensure the usability of health and healthcare data for research purposes on a large scale and with high data quality, structured and standardized data collection as well as secure and efficient data access are required. Interoperability must be ensured to enable the exchange between different IT systems across interfaces and the linkability of data from different sources.[439] Likewise, the data potentially usable for research should be findable, accessible, interoperable and reusable in accordance with the FAIR Data Principle.[440]

On the policy side, there are various initiatives aimed at promoting interoperability, access to data and the expansion of the data infrastructure. For example, researchers from medicine, computer science and other disciplines from all German university hospitals have been working together in consortia in the Medical Informatics Initiative (MII), which has been funded by the Federal Ministry of Education and Research since 2016, to develop interoperability solutions, among other things.[441] As part of the initiative, licences for the medical terminology SNOMED CT were used for the first time in Germany. Based on this terminology, a core data set is being built up by the consortia of the MII, which enables the overarching use of health data for research.[442]

The National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur, NFDI), which was adopted in 2018 and is currently under construction, pursues the systematic development, sustainable securing and accessibility of data from research and science. In this context, two consortia from the field of health research are being funded with the aim of creating new possibilities for data analysis and facilitating the shared use of health data.[443] The NFDI4Health consortium, the National Research Data Infrastructure for personal health data, focuses on data generated in clinical and public health studies, among others. The aim of the German Human Genome-Phenome Archive, the second funded consortium, is to establish a genome archive.

Box B 4-4 Findata

The example of Findata, an authority founded in Finland in 2019, shows how the secondary use of health data can be promoted and simplified. In a one-stop shop model for health data, Findata bundles the application processing as well as the linking and provision of the data. To gain access to the data, scientists only need to submit a single application. Once the application is approved, Findata processes the data, pseudonymizes it and makes it available to researchers remotely in protected virtual spaces.[444]

The administrative effort for accessing and using health data must be as low as possible for scientists. This task can be performed by the Research Data Centre Health, which is currently being set up and is modelled on Findata (see box B 4-4).[445] It can ensure efficient application and approval procedures for data use and guarantee data protection.

B 4-3 Barriers to Digital Transformation

Despite the great potential associated with digitalization for the improvement of care as well as the further development of the healthcare system, Germany lags far behind other European countries in international comparison. The reasons for this are complex and lie, among other things, in the structure of the healthcare system, considerations and concerns regarding data protection as well as a still too low acceptance of digital health applications both among service providers and patients.

Absence of an Overall Strategy

The multi-layered and heterogeneous landscape of stakeholders in the German healthcare system makes its digitalization a difficult undertaking. Initiatives in health research have been launched in recent years with the Telematics Infrastructure 2.0, the Medical Informatics Initiative and the NFDI consortia, which are intended to increase the networking of the stakeholders at national and European level and improve the utilization of data.[446] However, an overall strategy for the digitalization of the healthcare system is still lacking. This has now been announced in the coalition agreement.[447]

Balancing Act Between Data Protection, Data Security and Data Use

Health data is often sensitive personal data. Therefore, in the healthcare sector more than in other areas, there is a delicate balance between IT security and data protection on the one hand and the potential of data use on the other.

According to Article 9 of the European General Data Protection Regulation (GDPR), special care must be taken when collecting, passing on and using personal health data. This is often seen as a considerable obstacle to digitalization in the healthcare sector.[448] However, the GDPR allows for regulatory leeway at the national level. A look at other European countries such as Estonia and Denmark shows that the GDPR alone is not an obstacle to the use of data in the healthcare sector. There, GDPR-compliant opt-out regulations allow the transfer and use of data from electronic patient records for research purposes.[449] In Germany, comparable regulations are lacking so far.

Another obstacle is the multitude of Länder data protection laws, which are interpreted differently by the Länder data protection commissioners regarding the disclosure and use of health data for research purposes. This contributes to legal uncertainty and delays the implementation of data-dependent research projects.[450]

Hesitant Uptake of Digital Health Services

The digitalization of the healthcare system cannot be successfully implemented without the various stakeholders in the system accepting, understanding and applying the new technologies and applications. Service providers are hesitant about digital products. Reasons for this include a lack of information and digital skills.[451]

To bring digital applications such as ePR, e-prescription and DiGAs into widespread use, there must be a corresponding demand on the part of patients. In a representative survey conducted in May 2020, 55 percent of respondents said they were essentially open to new digital applications; more than 65 percent agreed that the COVID-19 pandemic had highlighted the positive benefits of these applications.[452] However, 45 percent of respondents expressed fears that digital applications would (tend to) worsen the doctor-patient relationship. Furthermore, 26 percent of respondents said that digital applications were too complicated and 40 percent that their data was not secure with them.[453] In addition, more than 40 percent of respondents said they did not feel well informed about digital applications by statutory health insurance funds and service providers.

Overall, these studies point to further potential for improvement on the part of both service providers and citizens, especially regarding the information base.

B 4-4 Recommendations for Action

The digitalization of the healthcare system is associated with great potential for innovation and value creation regarding better quality and more efficient healthcare. In particular, the increasing availability of health data in combination with new digital analysis methods creates opportunities for more personalized diagnostics and treatment. In international comparison, Germany lags far behind other European countries in the digitalization of the healthcare system.

The Commission of Experts recommends the following measures to the Federal Government to reduce existing barriers and to be able to leverage the innovation potential associated with digitalization:

Developing and Rapidly Implementing a Digitalization Strategy for the Healthcare Sector

— To advance the digital transformation of the healthcare system, the digitalization strategy for the healthcare system announced in the coalition agreement should be developed and implemented quickly. The strategy should specify concrete responsibilities, define milestones and set out a timetable for implementation.

— All relevant stakeholders of the healthcare system should be involved in the drafting and development of the strategy. The implementation of the strategy requires a coordinating body with the broadest possible enforcement powers. It must be carefully examined whether this role can be assigned to gematik, which according to the coalition agreement is to be expanded into a digital health agency.

- To enable an efficient and smooth exchange of data and information and to ensure interoperability between IT systems, sufficient space must be given to the establishment of interoperable and international standards within the framework of the strategy.

- In addition, continuous monitoring of the implementation progress and its regular publication should be integrated in the strategy.

Exploiting the Innovation Potential of Health Data

- The Commission of Experts supports the Health Data Use Act announced in the coalition agreement to improve the scientific use of health data. The GDPR-compliant use should be designed for scientists in such a way that the administrative burden is as low as possible.

- The Commission of Experts welcomes the fact that all insured persons are to be provided with a GDPR-compliant ePR via opt-out, which they can manage independently. However, to be able to exploit the potential associated with the ePR data, the option for insured persons to release the data should also be designed to be as low-threshold as possible – especially for research purposes, but also for the exchange of data between care and research.

Promoting the Use of Telemedicine Applications and DiGAs

- For the possibilities of telemedicine to be used more, sufficient financial incentives are required for the service providers. Where this is not currently the case, the same services should therefore be remunerated equally in the introductory phase, regardless of whether they are provided by telemedicine or conventionally.

- Potential providers of DiGAs must present comprehensive documentation of medical evidence as well as other satisfied factors as part of the accreditation process. Although this is a mandatory requirement for quality healthcare, the introduction of flexible, adaptive study designs and requirements should be explored. After approval, developers should continuously review the technical functionality and statutory health insurance funds the medical effectiveness of the DiGA.

- To provide incentives for quality improvement and assurance on the part of DiGA providers, suitable performance-based remuneration models should be introduced.

- To ensure the broad acceptance of digital health applications, the information base on the functionality, handling and added value of these applications should be improved.

Improving the Framework Conditions for Digitalization

- To improve the digital health literacy of health workers, digital elements should be increasingly integrated into the curricula of health professions.

- General digitalization barriers also affect the digitalization of the healthcare system. These include, above all, an insufficiently developed digital infrastructure, especially in rural areas. To advance the digital transformation in the healthcare sector, the Commission of Experts calls for the rapid quantitative and qualitative expansion of the digital infrastructure.

C

STRUCTURE AND TRENDS

C Structure and Trends

Download Data

Measuring and reporting Germany's performance as a location for research and innovation is an integral part of the Commission of Experts' annual reporting. The data is collected based on various indicators, which are divided into eight indicator sets organized by topics.

C 1 Education and Qualification

C 2 Research and Development

C 3 Innovation Behaviour in the Business Sector

C 4 Financing Research and Innovation

C 5 New Businesses

C 6 Patents

C 7 Scientific Publications

C 8 Production, Value Added and Employment

C 0 Overview

Measuring and reporting the performance of Germany as a location for research and innovation is an integral part of the Commission of Experts' annual reporting. The reporting is based on the presentation of various indicators that allow the drawing of conclusions about the dynamics and performance of the research and innovation system. For reasons of clarity, the indicators are divided into eight thematically ordered indicator sets. Using these sets of indicators, the performance of the German research and innovation system is presented in an intertemporal comparison as well as in comparison with the most important international competitors. Individual indicators are also reported at the level of the Länder to show differences in performance within Germany. Most indicators derive from the studies on the German innovation system commissioned by the Commission of Experts. In addition to the indicators listed here, these studies include further extensive indicator and analysis material. They can be viewed and downloaded on the Commission of Experts' website. The same applies to all figures and tables in the Annual Report as well as to the associated data sets.

C 1 Education and Qualification

Investments in education and a high level of qualification strengthen a country's medium- and long-term innovative capacity and economic growth. The indicators listed in chapter C 1 provide information on the qualification status and provide an overview of the strengths and weaknesses of Germany as a location for innovation. The international comparison allows an assessment of how these findings compare to other industrialized nations.

C 2 Research and Development

Research and development processes are an essential prerequisite for the creation of new products and services. In principle, a high R&D intensity has positive effects on competitiveness, growth and employment. R&D investments and activities by companies, tertiary education institutions and the public sector therefore provide essential clues for assessing a country's technological performance. Chapter C 2 outlines how Germany compares internationally in terms of its R&D activities, the extent to which the individual Länder invest and which economic sectors are particularly research-intensive.

C 3 Innovation Behaviour in the Business Sector

Innovation activities of companies aim to create competitive advantages through innovation. A product innovation is when a new or improved good is launched on the market whose characteristics differ from the goods previously offered on the market. The introduction of a new or improved manufacturing process is called a process innovation. The presentation of the innovation behaviour of the German economy in an international comparison in chapter C 3 is based on the innovation intensity in industry and knowledge-intensive services as well as on the percentage of turnover generated by new products.

C 4 Financing Research and Innovation

Financing business and especially R&D activities is a key challenge, especially for young, innovative companies. As these companies initially generate little or no turnover, financing out of their own resources is hardly possible. Debt financing is difficult because it is hard for investors such as banks to assess the prospects of success for innovative start-ups. Alternative ways of company funding include raising equity capital or venture capital as well as financing through government funding. Chapter C 4 describes the availability of venture capital and public sector R&D funding in Germany and in an international comparison.

C 5 New Businesses

Start-ups, especially in research- and knowledge-intensive sectors, challenge established companies with innovative products, processes and business models. The establishment of new companies and the exit of unsuccessful (or no longer successful) companies from the market is an expression of innovation competition for the best solutions. The business dynamics described in chapter C 5 are therefore an important aspect of structural change. Especially in new fields of technology, in the emergence of new demand trends and in the early phase of transferring scientific findings to the development of new products and processes, young companies can open new markets and help innovative ideas achieve a breakthrough.

C 6 Patents

Patents are industrial property rights for new technical inventions. Consequently, they often form the basis for the valorization of innovations on the market and at the same time support coordination as well as the knowledge and technology transfer between stakeholders in the innovation system. Chapter C 6 illustrates the patent activities of selected countries. It also examines the extent to which these countries have specialized in the areas of high-value technology and cutting-edge technology.

C 7 Scientific Publications

The continuous generation of new knowledge is particularly dependent on the performance of the respective research and science system. With the help of bibliometrics, this performance is presented in chapter C 7 in an international comparison. The performance of a country is determined based on the publications of its scientists in scientific journals. The perception and importance of these publications is captured by the number of citations.

C 8 Production, Value Added and Employment

The share of labour input and value added in research-intensive and knowledge-intensive sectors in a country reflects their economic importance and allows conclusions to be drawn about a country's technological performance. Chapter C 8 presents the development of value added and productivity in research-intensive industries and knowledge-intensive services in an international comparison. In addition, Germany's world trade position in research-intensive goods and knowledge-intensive services is shown.

C 1 Education and Qualification[454]

The percentage of the labour force with tertiary qualifications (ISCED 5+6 and ISCED 7+8) was 33.8 percent in Germany in 2020, significantly lower than in most comparative countries (C 1-1). In terms of higher academic qualifications (ISCED 7+8), Germany's share of 14.5 percent was also around 3 percentage points below the average for the countries under consideration. By contrast, with 55.1 percent in a European comparison, Germany has by far the highest proportion of intermediate degrees (ISCED 3** and ISCED 4) that formally allow entry to the tertiary level.

The share of first-year students in the age-matched population of under-25s (C 1-2) increased by 4 percentage points to 56 percent in Germany in 2019 compared to the previous year. The adjusted rate for under-25s and excluding international first-year students in Germany in 2019 was 49 percent, also 4 percentage points higher than in 2018.

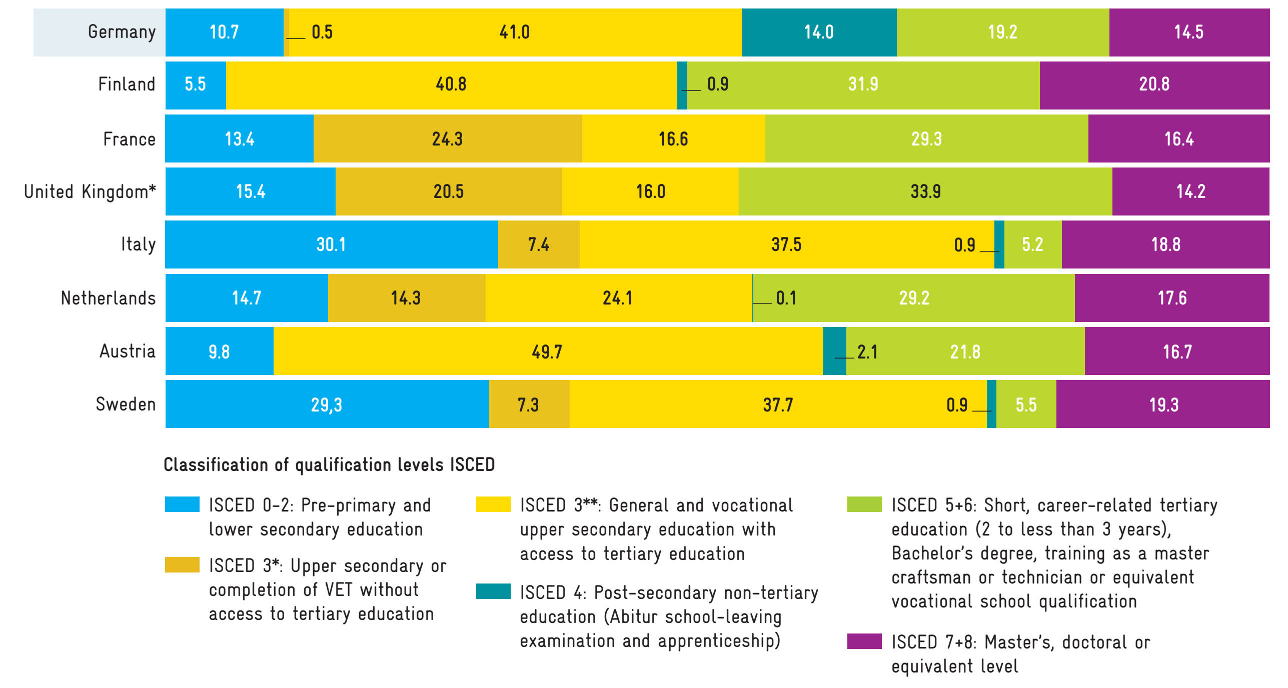
The number of students entitled to study in 2020 has decreased by almost 35,000 to 381,951 compared to the previous year. The rate of qualified school-leavers, i. e. the proportion of those eligible to study as a percentage of the population of the corresponding age, fell to 44.6 percent in 2020 (C 1-3), but is estimated to rise again to 50 percent by 2030.[455]

The number of 'Bildungsinländer', i. e. those students without German citizenship who acquired their entitlement to study in Germany, was 91,708 in 2020, the equivalent of the previous year's figure of 91,699 (C 1-4). On the other hand, the total number of foreign students in Germany increased again, despite a sharp 22 percent decline in the number of international first-year students. The number of foreign students, i. e. students without German citizenship who have acquired their entitlement to study abroad and are enrolled at German higher education institutions, was in 2020 around 1.5 percent higher than in 2019.

In 2020, the number of first-time graduates (C 1-5) fell by 6.8 percent compared to the previous year, a much sharper decline than in previous years.[456] The number of first-time graduates in the STEM field in particular fell at an above-average rate.

In 2020, the rate of people aged 25 to 64 who participated in continuing education and training (CET) in the last four weeks (C 1-6) reached 4.2 percent, by far the lowest value in the observation period from 2010 to 2020. On average, the individual CET rate fell by 0.8 percentage points compared to 2019. The participation of businesses in CET reached 54.9 percent in 2019, 0.4 percentage points higher than the year before.

Fig. C 1-1 Qualification levels of gainfully employed persons in selected countries 2020 in percent



* Data as from 2019.
The ISCED education levels are recognized UNESCO standards for international comparisons of country-specific education systems.
Source: Eurostat, European Union Labour Force Survey. Calculations by CWS in Kerst et al. (2022).

Download Data

Tab. C 1-2 Number of new tertiary students in the age-matched population of under-25s in selected countries 2013–2019 in percent

Countries	2013[1]	2014[1]	2015[1]	2016[1]	2017[1]	2018[1]	2019[1]	2013[2]	2014[2]	2015[2]	2016[2]	2017[2]	2018[2]	2019[2]
Belgium	64	64	66	69	73	68	66	54	57	59	62	67	62	61
Germany[3]	51	54	53	51	52	52	56	46	48	46	45	45	45	49
Finland	45	44	46	46	47	47	48	41	40	42	42	43	43	45
United Kingdom	48	54	56	60	61	63	66	42	47	49	52	53	54	57
Italy	40	40	42	43	46	48	49	–	–	41	41	43	46	48
Japan	–	–	–	–	71	73	72	–	–	–	–	–	–	–
Sweden	42	45	45	44	45	46	46	40	42	41	40	41	41	41
Switzerland	48	55	55	55	56	48	50	–	47	47	47	47	40	42
USA	48	48	48	47	46	46	45	47	47	46	46	44	44	43
OECD average	–	–	–	–	–	54	56	50	51	48	49	50	49	51

1) The entry rates for under-25s are given according to the ISCED 2011 classification for levels 5, 6, 7 and 8.
2) Adjusted rate for under-25s, excluding international first-year students.
3) Since 2019, including professional advancement trainings.
Source: OECD (Ed.): Education at a Glance, various volumes; as well as OECD database stats.oed.org in Kerst et al. (2022).

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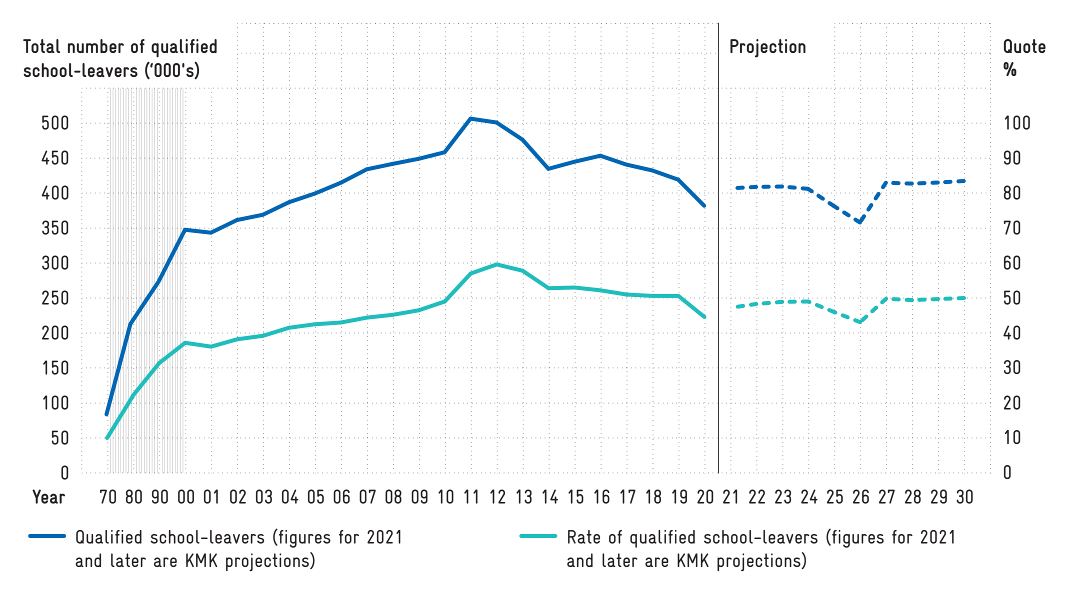
Fig. C 1-3 School-leavers qualified for higher education in Germany 1970–2030

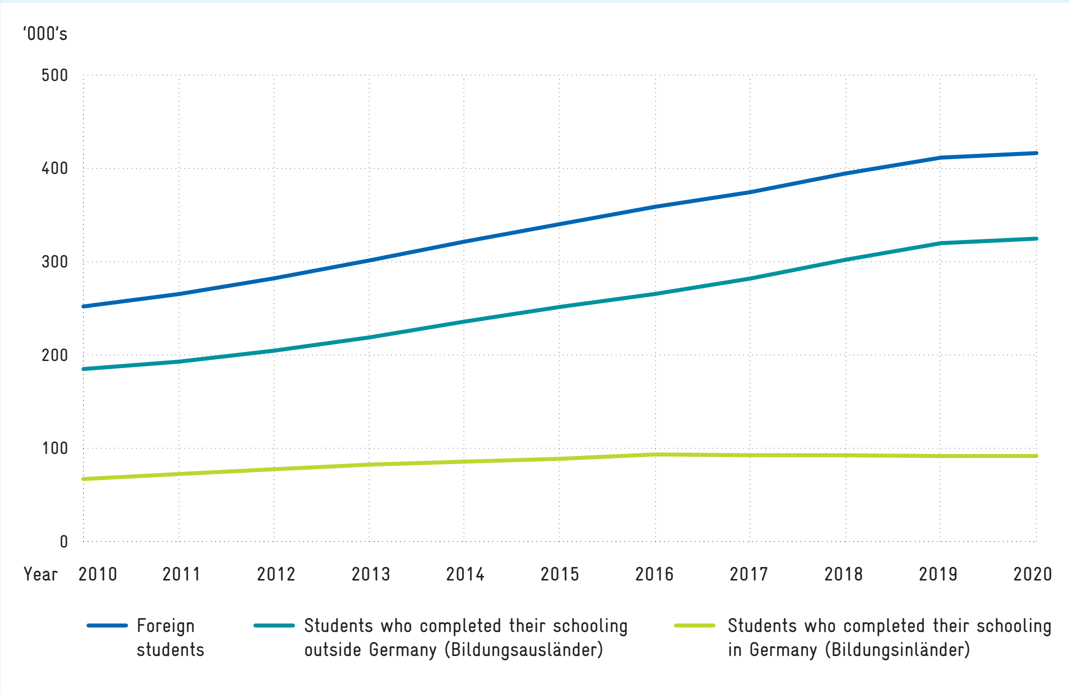
Download Data



School-leavers qualified for higher education: either with a 'general' or a 'technical' school-leaving certificate* (in Germany: Abitur).
Rate of qualified school-leavers: number of school-leavers qualified for higher education as a percentage of the relevant age group. Since 2012, rates taking into account the results of the 2011 census.
Source of actual figures: Federal Statistical Office in Kerst et al. (2022).
Source of forecast figures: Statistical publications by the Standing Conference of the Ministers of Education and Cultural Affairs (Kultusministerkonferenz, KMK) in Kerst et al. (2022).

Fig. C 1-4 Foreign students at German tertiary education institutions 2010–2020[1)]

Download Data



Foreign students are defined as persons without German citizenship. They can be divided into students who attained their higher-education entrance qualification in Germany (Bildungsinländer), and those who attained this qualification abroad (Bildungsausländer).
1) The data are submitted annually by the higher education institutions to the statistical offices in the winter semester after the end of the enrolment period.
Source: Federal Statistical Office, research by DZHW-ICE in Kerst et al. (2022).

Tab. C 1-5 First-time graduates and subject structure rate 2015–2020

Download Data

	2015	2016	2017	2018	2019	2020
Total number of graduates	317,102	315,168	311,441	303,155	310,747	289,615
Percentage of women	51.1	52.0	52.6	53.0	53.6	53.7
Percentage of graduates from universities	56.8	54.7	53.9	53.0	52.8	50.7
Humanities	37,135	34,886	32,205	30,491	30,660	27,633
Share subject group in percent	11.7	11.1	10.3	10.1	9.9	9.5
Legal, economics and social sciences	128,273	132,737	134,605	131,832	135,165	128,531
Share subject group in percent	40.5	42.1	43.2	43.5	43.5	44.4
Human medicine, health sciences	17,935	19,521	20,308	20,101	21,957	20,309
Share subject group in percent	5.7	6.2	6.5	6.6	7.1	7.0
Agriculture, forestry and nutritional sciences, veterinary medicine	7,442	6,978	7,148	7,252	7,226	7,104
Share subject group in percent	2.3	2.2	2.3	2.4	2.3	2.5
Art, art history	11,514	11,268	11,119	10,892	10,905	9,754
Share subject group in percent	3.6	3.6	3.6	3.6	3.5	3.4
Mathematics, natural sciences	30,001	28,081	26,261	25,677	26,765	23,627
Share subject group in percent	9.5	8.9	8.4	8.5	8.6	8.2
Engineering	81,300	78,552	76,133	73,849	74,868	69,547
Share subject group in percent	25.6	24.9	24.4	24.4	24.1	24.0

First-degree graduates and subject-structure ratio: First-degree graduates are persons who have successfully completed a first degree course. The subject-structure ratio indicates the percentage of first-degree graduates who have completed their degree course in a specific subject or group of subjects.
Source: Federal Statistical Office as well as research by DZHW-ICE in Kerst et al. (2022).

Tab. C 1-6 Participation of individuals and companies engaging in continuing education and training (CET) 2010–2020 in percent

Download Data

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
a) Individual CET rate	4.9	4.9	5.1	4.9	4.8	4.9	5.2	5.0	4.9	5.0	4.2
Gainfully employed persons by qualification level	5.6	5.6	5.9	5.6	5.5	5.5	5.8	5.4	5.3	5.4	4.7
low (ISCED 0–2)	1.3	1.0	1.4	1.4	1.3	1.2	1.5	1.5	1.3	1.5	1.7
medium (ISCED 3–4)	3.9	3.9	4.1	3.9	4.2	4.3	4.5	4.2	4.0	4.2	3.6
high (ISCED 5–8)	10.5	10.3	10.6	10.1	9.4	9.3	9.7	8.9	8.9	8.9	7.6
Unemployed persons by qualification level	3.9	4.6	3.8	3.6	3.7	3.7	4.2	5.3	5.1	4.5	–[1]
low (ISCED 0–2)	3.5	3.6	3.1	2.9	2.8	2.6	3.3	5.1	4.9	3.3	–[1]
medium (ISCED 3–4)	3.2	4.0	3.6	3.4	3.3	3.4	3.6	4.3	4.2	3.0	4.4
high (ISCED 5–8)	8.3	10.0	6.6	5.4	6.4	6.3	7.2	8.6	7.7	9.8	–[1]
Inactive persons by qualification level	2.0	1.9	1.6	1.8	1.8	2.0	2.4	3.2	2.9	2.7	2.2
low (ISCED 0–2)	1.6	1.5	1.4	1.4	1.3	1.7	2.5	4.0	3.8	3.4	2.0
medium (ISCED 3–4)	1.8	1.9	1.4	1.5	1.6	1.6	1.8	2.2	2.0	2.0	1.5
high (ISCED 5–8)	3.6	2.7	2.8	3.5	3.4	3.7	4.4	4.9	4.2	3.9	4.6
b) Corporate participation in CET[2]	44.1	52.6	53.1	52.1	53.6	52.8	53.2	53.0	54.5	54.9	–
By sector											
Knowledge-intensive manufacturing	55.9	62.9	65.5	66.7	69.9	70.6	64.0	65.0	63.0	66.6	–
Non-knowledge-intensive manufacturing	33.3	41.2	43.2	41.8	43.0	44.5	46.3	45.5	46.0	49.6	–
Knowledge-intensive services	57.1	68.7	67.2	67.4	67.0	67.5	69.2	66.1	69.1	66.5	–
Non-knowledge-intensive services	37.5	44.9	45.3	44.3	46.0	43.8	43.7	45.2	46.8	46.9	–
Non-commercial industry	51.2	59.0	60.3	58.4	61.9	60.1	59.3	59.3	60.0	60.9	–
By company size											
< 50 employees	41.8	50.5	50.9	49.8	51.4	50.5	50.8	50.6	51.9	52.5	–
50–249 employees	83.3	90.8	89.7	90.1	90.8	89.3	89.5	89.0	92.0	90.0	–
250–499 employees	93.3	95.9	96.5	97.0	96.9	96.8	96.4	96.0	97.2	97.2	–
≥ 500 employees	97.9	98.4	97.8	99.1	99.1	97.1	97.9	97.2	97.9	–[3]	–

Individual CET rate: Percentage of people who participated in CET in the last four weeks prior to the time of the survey.
Corporate participation in CET: percentage of companies where employees were released for CET or whose CET costs were paid.
On ISCED see C 1-1.
Population a): All persons aged between 25 and 64.
Population b): All establishments with at least one employed person subject to social insurance contributions.
[1] Not shown due to lack of reliable data.
[2] The data for corporate CET participation in 2020 were not yet available by the editorial deadline.
[3] Figures censored for data protection reasons, as they are only just below 100 percent.
Source a): European Union Labour Force Survey (special evaluation). Calculations by CWS in Kerst et al. (2022). Data as from 2016 relating to unemployed and inactive persons are comparable to previous years only to a limited extent due to methodological changes and stricter confidentiality rules.
Source b): IAB Establishment Panel (special evaluation). Calculations by CWS in Kerst et al. (2022).

C 2 Research and Development[457]

Statistics on research and development (R&D) expenditure indicate the extent to which activities to generate new ideas are developed. R&D intensity, as a share of R&D expenditure in the gross domestic product (for countries) or in turnover (for companies), provides information on the willingness to invest in R&D; the distribution of R&D expenditure across sectors and industries indicates focal points of R&D activity.

The R&D intensity (C 2-1) in Germany, i. e. the share of R&D expenditure in gross domestic product, is 3.19 percent. Thus, Germany continues to demonstrate an increasing R&D intensity. South Korea achieved by far the highest R&D intensity in 2019 of all considered countries with 4.64 percent. The USA's increased from 2.95 percent[458] in 2018 to 3.07 percent in 2019. China's R&D intensity grew less strongly, increasing by 0.09 percentage points compared to the previous year to 2.23 percent in 2019. Japan is the only one of the selected countries whose R&D expenditure in relation to gross domestic product fell slightly from 2018 to 2019.

Germany's budget estimate for civil R&D (C 2-2)[459] increased again compared to 2019, reaching an index value of 137 percent in 2020. This means that the budget allocated in the German national budget for financing R&D has increased by 37 percent between 2010 and 2020. The budget for civil R&D in Japan, Switzerland and South Korea has also risen sharply. For South Korea and Switzerland, however, data are only available up to 2019.

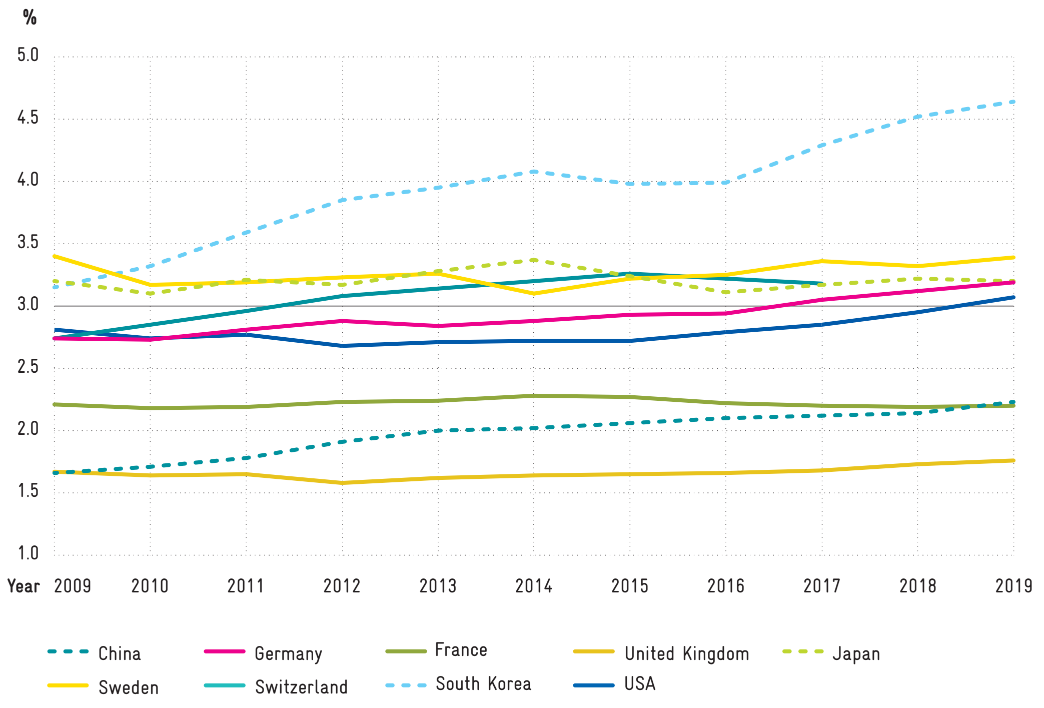
The distribution of gross domestic expenditure on R&D by performing sector (C 2-3) shows that the share of expenditure on R&D performed in the general government sector declined between 2010 and 2019 for all considered countries, except for Switzerland. The share of expenditure fell particularly sharply in the UK (by 2.9 percentage points to 6.6 percent) and in the USA (by 2.8 percentage points to 9.9 percent). In Germany, on the other hand, it decreased by only 1.1 percentage points to 13.7 percent.

The R&D intensity of the German Länder (C 2-4) indicates the share of R&D expenditure in the gross domestic product of the Länder for 2009 and 2019. R&D intensity increased between 2009 and 2019 in all Länder except Berlin and Mecklenburg-Western Pomerania. Baden-Württemberg recorded the highest R&D intensity, improving from 4.62 percent in 2009 to 5.79 percent in 2019.

The internal R&D expenditure of companies in Germany (C 2-5) amounted to more than €75.8 billion in 2019, of which more than €30.2 billion went to vehicle manufacturing, far ahead of electronics with more than €11.4 billion. Internal R&D expenditure as a percentage of total turnover (C 2-6)[460] increased from 2.8 percent to 3.0 percent on average for the manufacturing sector from 2017 to 2019.

Fig. C 2-1 R&D intensity in selected countries 2009–2019 in percent

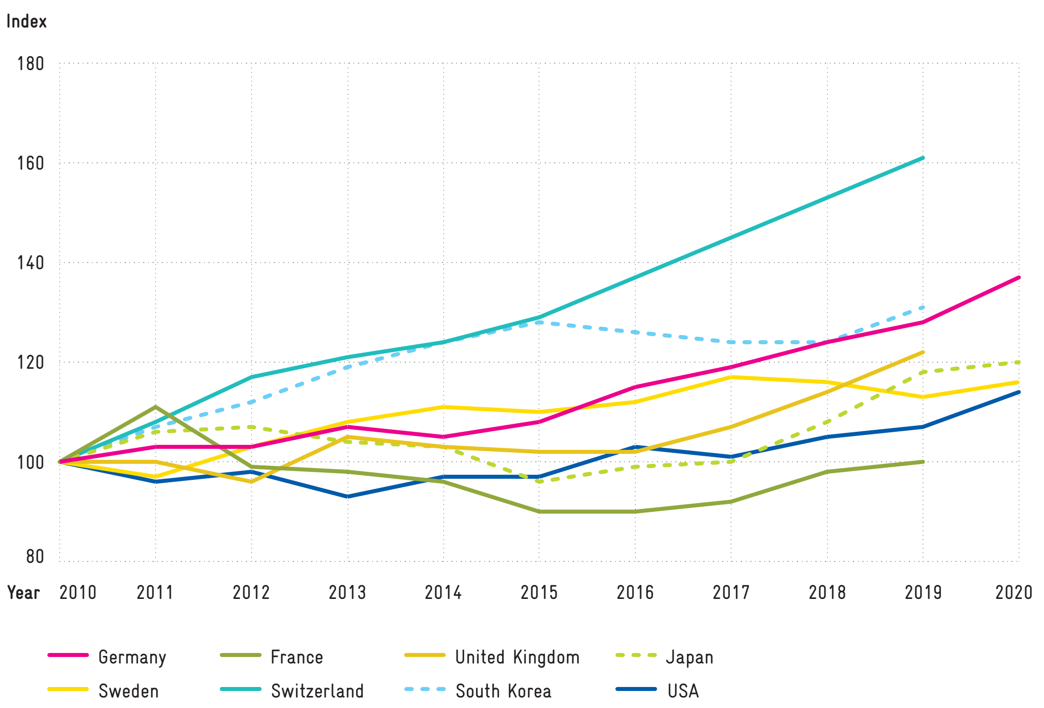
Download Data



R&D intensity: percentage of an economy's gross domestic product (GDP) spent on R&D. Data for Switzerland are only available up to 2017.
Source: OECD. Calculations and estimates by DIW Berlin in Kladroba et al (2022).

Fig. C 2-2 State budget estimates for civil R&D in selected countries 2010–2020 (index values)

Download Data



R&D budget estimates: the chart shows the amounts set aside in the budget to finance R&D.
Index: 2010 = 100, data partly based on estimates.
Source: OECD, Eurostat. Calculations and estimates by DIW Berlin in Kladroba et al (2022).

Tab. C2-3 Distribution of gross domestic expenditure on R&D (GERD) by performing sector in selected countries in 2010 and 2019

Download Data

Countries	2010					2019				
	GERD in US$m	of which (%) carried out by ...				GERD in US$m	of which (%) carried out by ...			
		Business sector	Tertiary education institutions	Public sector	Private non-profit*		Business sector	Tertiary education institutions	Public sector	Private non-profit*
China	212,138	73.4	8.5	18.1	0.0	525,693	76.4	8.1	15.5	0.0
Germany	87,036	67.0	18.2	14.8	0.0	148,150	68.9	17.4	13.7	0.0
France	50,901	63.2	21.6	14.0	1.2	73,287	65.8	20.1	12.4	1.8
United Kingdom	37,568	60.9	27.0	9.5	2.5	56,936	66.6	23.1	6.6	2.3
Japan	140,566	76.5	12.9	9.0	1.6	173,267	79.2	11.7	7.8	1.3
Sweden	12,554	68.7	26.3	4.9	0.0	19,269	71.7	23.7	4.5	0.1
Switzerland[1)]	10,917	73.5	24.2	0.7	1.6	18,566	71.0	28.2	0.8	2.3
South Korea	52,166	74.8	10.8	12.7	1.7	102,521	80.3	8.3	10.0	1.4
USA	410,093	68.0	14.7	12.7	4.5	657,459	73.9	12.0	9.9	4.3

1) For Switzerland, 2017 was used as the latest available year.
* Non-profit organizations included in 'Public sector' in some countries.
Source: OECD. Calculations by DIW Berlin in Kladroba et al (2022).

Tab. C2-4 R&D intensity of the Länder and Germany 2009 and 2019 in percent

Download Data

Länder	2009				2019			
	Total	Business sector	Public sector	Tertiary education institutions	Total	Business sector	Public sector	Tertiary education institutions
Baden-Württemberg	4.62	3.68	0.43	0.52	5.79	4.84	0.42	0.53
Bavaria	3.04	2.35	0.28	0.41	3.41	2.61	0.33	0.47
Berlin	3.37	1.38	1.14	0.85	3.33	1.33	1.17	0.83
Brandenburg	1.40	0.35	0.72	0.32	1.81	0.65	0.78	0.39
Bremen	2.65	0.98	0.91	0.76	3.01	0.99	1.23	0.79
Hamburg	2.11	1.18	0.45	0.49	2.18	1.22	0.38	0.57
Hesse	2.97	2.36	0.22	0.39	3.10	2.30	0.34	0.47
Mecklenburg-Western Pomerania	1.84	0.58	0.71	0.54	1.81	0.51	0.65	0.65
Lower Saxony	2.60	1.72	0.40	0.49	3.14	2.24	0.35	0.55
North Rhine-Westphalia	1.97	1.19	0.31	0.47	2.16	1.26	0.33	0.57
Rhineland-Palatinate	2.03	1.48	0.16	0.38	2.62	1.97	0.21	0.45
Saarland	1.26	0.50	0.37	0.38	1.90	0.89	0.44	0.58
Saxony	2.73	1.20	0.83	0.70	2.99	1.31	0.83	0.85
Saxony-Anhalt	1.37	0.44	0.48	0.45	1.54	0.41	0.54	0.59
Schleswig-Holstein	1.29	0.58	0.35	0.36	1.68	0.79	0.35	0.53
Thuringia	2.18	1.06	0.53	0.59	2.35	1.16	0.53	0.66
Germany	2.74	1.85	0.41	0.49	3.19	2.20	0.44	0.56

R&D intensity: Länder expenditure on research and development as a percentage of their gross domestic product, broken down by performing sector. GDP as of 22 Oct. 2021.
Source: SV Wissenschaftsstatistik and statistical offices of the Federal Government and the Länder. Calculations by SV Wissenschaftsstatistik in Kladroba et al (2022).

Tab. C 2-5 Internal corporate R&D expenditure by origin of funds, economic sectors, company size and technology category in 2019

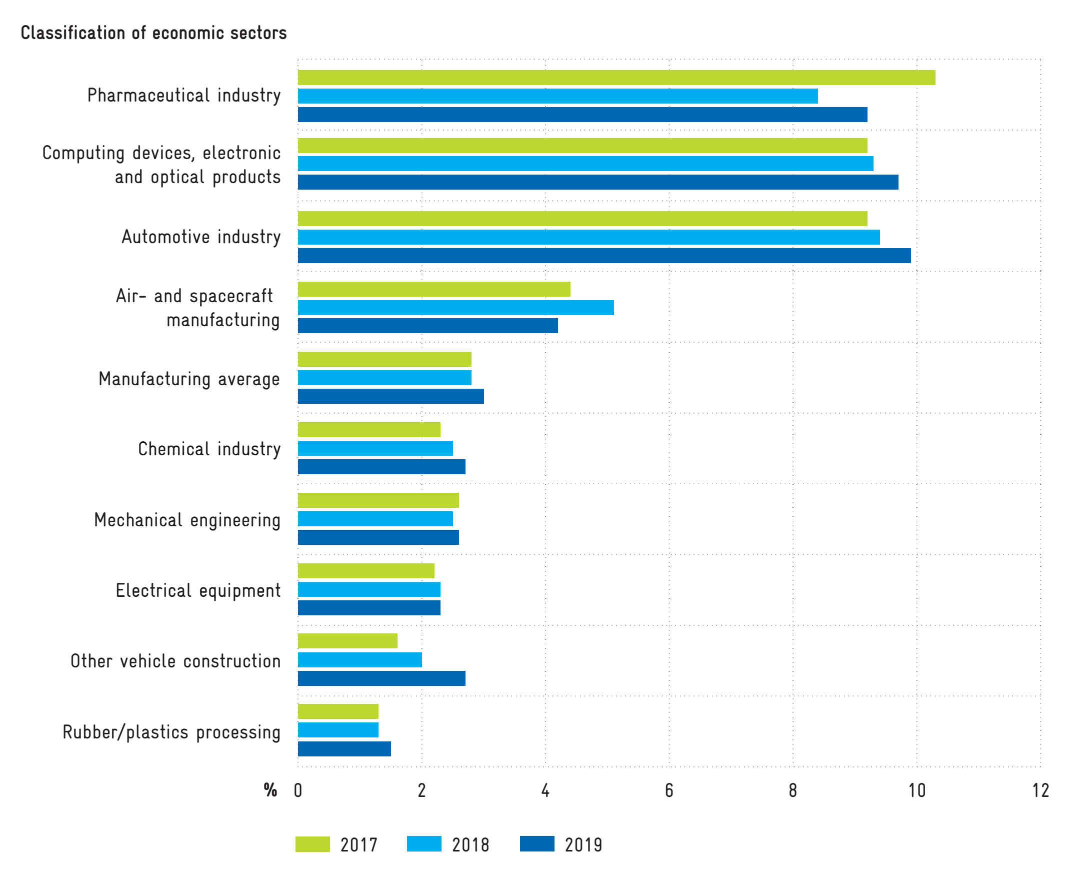
Download Data

	Internal R&D expenditure				
	in total	of which funded by			
		Business sector	Public sector	Other domestic entities (e.g. universities)	Foreign entities
	in 1,000 euro	in percent			
All researching companies	**75,830,367**	**88.2**	**3.2**	**0.1**	**8.5**
Manufacturing	64,361,021	89.0	2.0	0.1	8.9
Chemical industry	4,411,372	92.7	1.4	0.0	5.9
Pharmaceutical industry	5,433,856	82.4	0.9	0.0	16.6
Plastics, glass and ceramics	1,708,901	90.6	2.8	0.1	6.6
Metal production and processing	1,567,668	80.3	9.8	0.3	9.5
Electrical engineering/electronics	11,416,474	88.2	3.1	0.0	8.7
Mechanical engineering	7,450,294	94.5	2.5	0.3	2.7
Vehicle construction	30,230,207	88.9	1.1	0.2	9.8
Other manufacturing industries	2,142,249	90.5	3.5	0.1	5.9
Remaining economic sectors	11,469,346	83.4	10.1	0.2	6.3
< 100 employees	3,815,854	70.2	23.2	0.5	6.0
100–499 employees	6,265,028	85.3	7.3	0.2	7.2
500–999 employees	4,189,250	90.5	2.5	0.1	7.0
≥ 1,000 employees	61,560,235	89.4	1.6	0.1	8.9
Technology categories in industry					
Cutting-edge technology (> 9 percent of costs/turnover spent on R&D)	16,239,674	84.3	3.6	0.0	12.0
High-value technology (3–9 percent of costs/turnover spent on R&D)	42,032,649	90.8	1.0	0.2	8.0

Internal R&D: R&D that is conducted within the company, either for the company's own purposes or commissioned by a third party.
Source: SV Wissenschaftsstatistik in Kladroba et al. (2022).

Fig. C 2-6 Internal corporate R&D expenditure as a percentage of turnover 2017–2019

Download Data



Internal R&D: R&D that is conducted within the company, either for the company's own purposes or commissioned by a third party.
Internal R&D expenditure is reported as a percent of total turnover and not as a percent of turnover from own products. Figures net, without input tax.
Source: SV Wissenschaftsstatistik, Federal Statistical Office. Calculations by SV Wissenschaftsstatistik in Kladroba et al (2022).

C 3 Innovation Behaviour in the Business Sector

The Europe-wide Community Innovation Survey (CIS), conducted every two years and coordinated by Eurostat, forms the data basis for the international comparison of the innovation behaviour of companies (C 3-1).[461] It is aimed at companies with ten or more employees in manufacturing industry and in selected service sectors. In 2018, the innovation intensity, i. e. innovation expenditure in relation to total turnover, of research-intensive industry in Germany was 7.4 percent and thus above the rates of the comparative countries. In knowledge-intensive services, Sweden and Finland recorded the highest innovation intensities of the comparative countries, at 5.6 and 4.3 percent, respectively. In Germany, the rate was 3.2 percent.

The data on the innovation behaviour of the German economy in the period 2010 to 2020 presented in figures C 3-2 and C 3-3 are based on the innovation survey conducted annually since 1993 by the ZEW – Leibniz Centre for European Economic Research, the Mannheim Innovation Panel (MIP).[462] Data from the MIP represents the German contribution to the CIS survey. However, in addition to the data to be reported to Eurostat, the MIP also includes data for enterprises with five to nine employees.

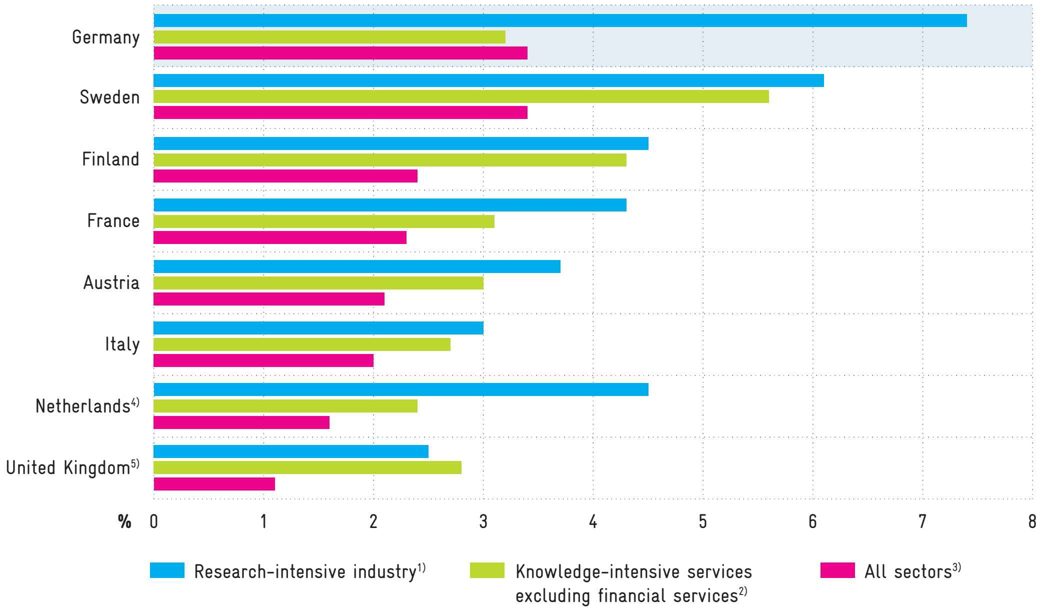
Innovation intensity (C 3-2) increased slightly in 2020 compared to the previous year in both R&D-intensive industry (from 8.9 to 9.3 percent) and knowledge-intensive services (from 6.1 to 6.3 percent) in a year marked by the COVID-19 crisis. In other industry (1.4 percent), other services (0.6 percent) and financial services (0.9 percent) it remained at the respective previous year's level.

The percentage of turnover from new products (C 3-3), as a measure of the innovation success of companies, declined slightly in R&D-intensive industry in 2020 compared to the previous year (from 31.2 to 30.6 percent), continuing the slightly declining trend of previous years. An increase compared to the previous year was recorded in other industry (from 7.0 to 7.4 percent), knowledge-intensive services (from 13.6 to 14.7 percent) and other services (from 6.4 to 6.8 percent).

An important aspect in the commercialization of innovative technologies is standardization. At the international level, norms and standards are developed in the committees of the International Organization for Standardization (ISO). Through its involvement in these committees, a country can have a significant influence on global technical infrastructures (C 3-4).[463] In 2021, German companies were involved in the work of the ISO significantly more often than representatives of other countries but have hardly changed their involvement compared to 2011.[464] In the ten-year period from 2011 to 2021, China and Japan in particular have significantly increased their participation in the ISO.

Fig. C 3-1 Innovation intensity in European comparison in 2018 in percent

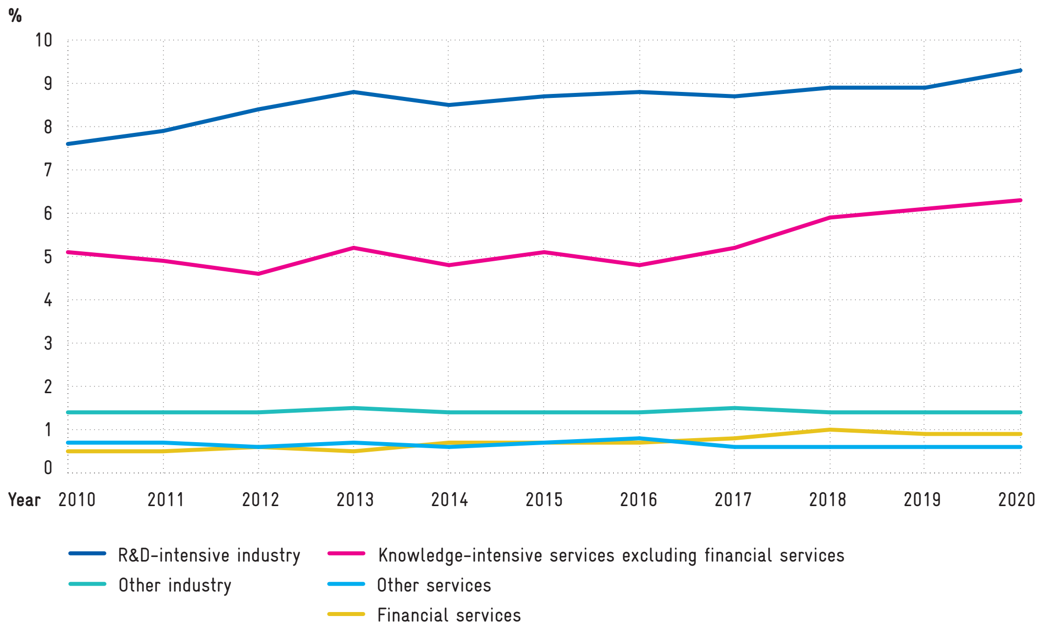
Download Data



Innovation intensity: innovation expenditure by companies as a percentage of their total turnover.
1) Research-intensive industry: divisions 19-22, 25-30 of WZ classification. Since data for all economic sectors are not available for all countries, the definition of research-intensive industry in the European comparison differs from the definition otherwise used by the EFI.
2) Knowledge-intensive services excluding financial services: divisions 58-63, 71-73 of WZ classification. Since data for all economic sectors are not available for all countries, the definition of knowledge-intensive services in the European comparison differs from the definition otherwise used by the EFI.
3) All sectors: divisions 5-39, 46, 49-53, 58-66, 71-73 of the WZ.
4) Reference year 2016. Research-intensive industry only divisions 25-30 of the WZ
5) Reference year 2016.
Source: Eurostat, Community Innovation Surveys 2018 and 2016. Calculations by ZEW.

Fig. C 3-2 Innovation intensity in industry and business-oriented services in Germany 2010–2020 in percent

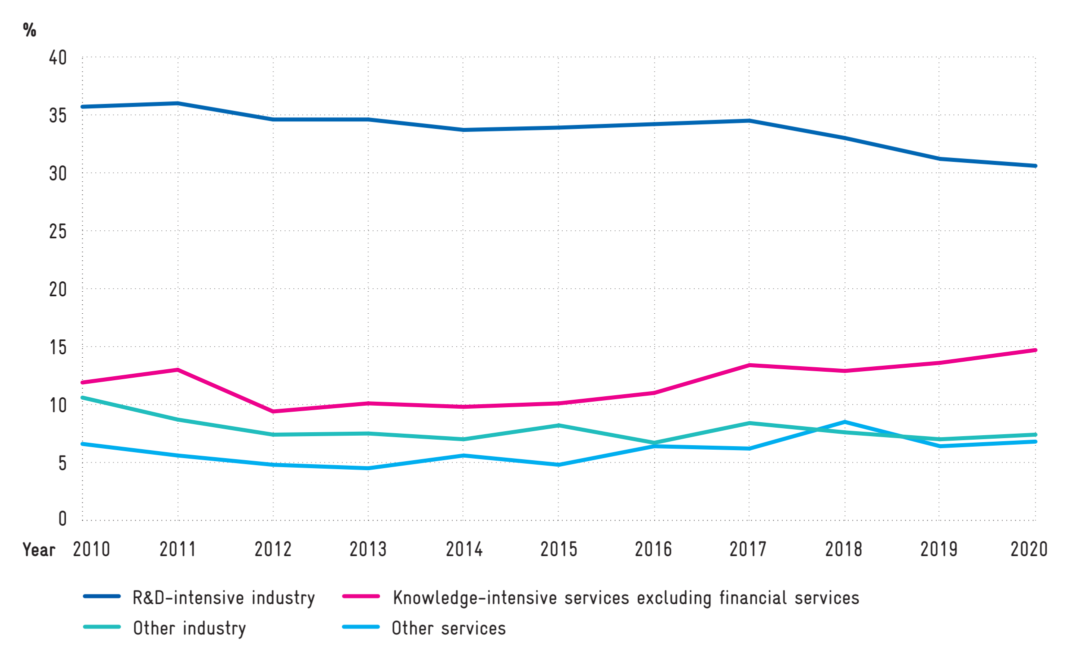
Download Data



Innovation intensity: innovation expenditure by companies as a percentage of their total turnover.
Source: Mannheim Innovation Panel. Calculations by ZEW.

Fig. C 3-3 Percentage of turnover generated by new products in industry and business-oriented services in Germany 2010–2020 in percent

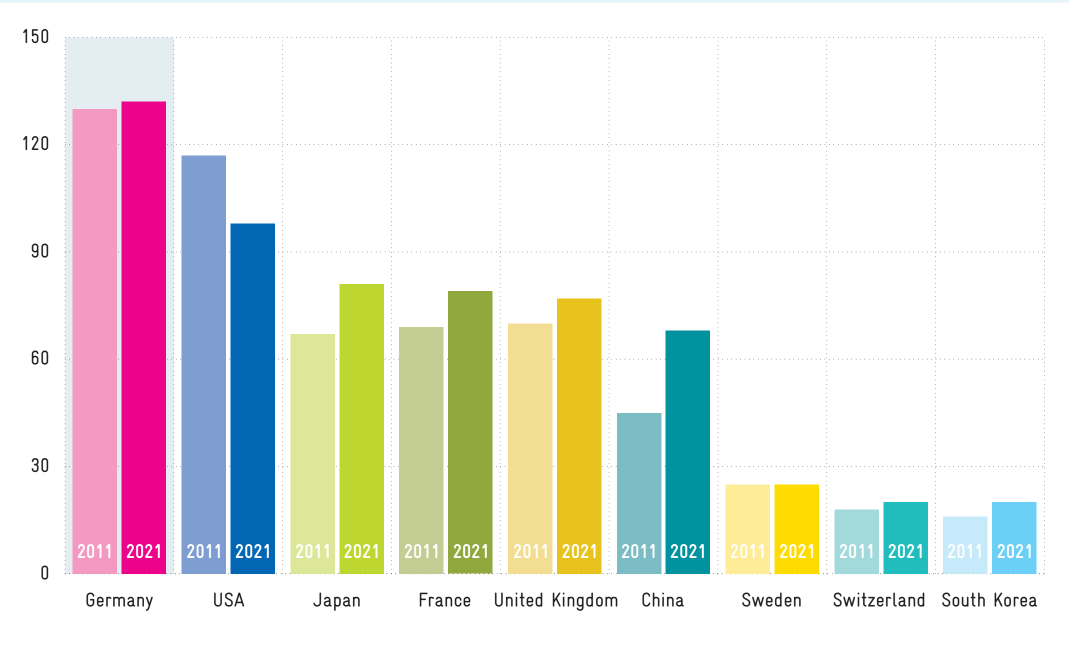
Download Data



Source: Mannheim Innovation Panel. Calculations by ZEW.

Fig. C 3-4 Number of secretariats listed by the technical committees and subcommittees of the International Organization for Standardization (ISO) in 2011 and 2021

Download Data



Source: Own representation based on ISO (2012) and https://www.iso.org/members.html (accessed on 23 December 2021).

C 4 Financing Research and Innovation[465]

Public funding of research and development (R&D) in the business sector can take the form of direct R&D funding or indirect R&D funding (fiscal R&D funding). Figure C 4-1 shows the share of direct and indirect R&D funding in the business sector in the gross domestic product (GDP) in selected countries. It is clearly visible that Germany is only ahead of Switzerland in this group. The instrument of fiscal R&D funding was available to companies in most of the countries listed in the year under review (2018); Germany did not yet make use of this funding option in 2018. The Research Allowance Act (Forschungszulagengesetz) only came into force in Germany at the beginning of 2020.

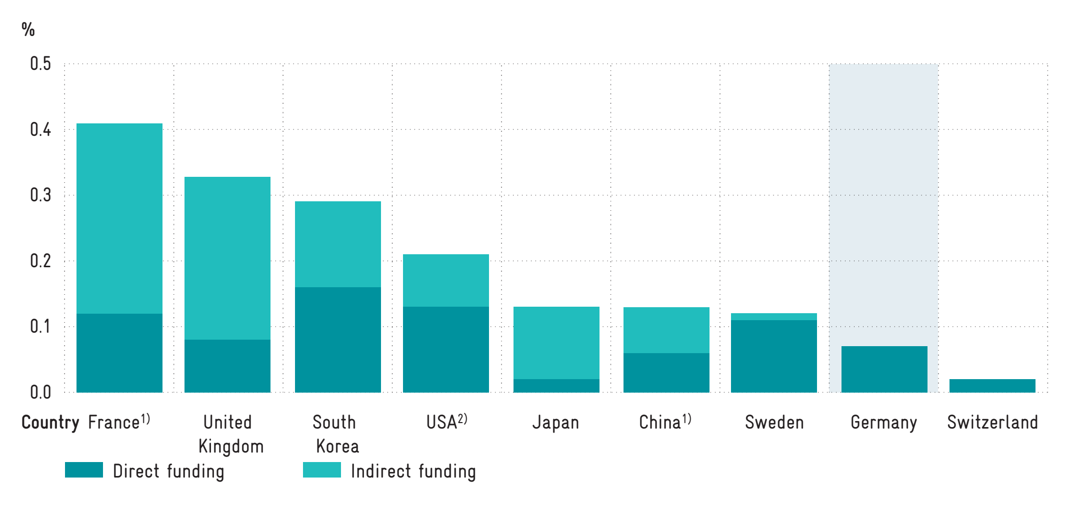
Figure C 4-2 provides an overview of the share of venture capital investments in the national GDP of selected countries. For the comparison, data from Invest Europe are used, which are easily comparable internationally due to the harmonized collection and processing.[466] The highest venture capital investments relative to GDP in 2020 were recorded in Finland and the United Kingdom. Germany only occupies a position in the lower midfield within the European peer group and the share of venture capital investments in GDP fell slightly in 2020 compared to the previous year.

Since Invest Europe data only covers venture capital investments by companies organized in the association, there is a risk of underestimating the volume.[467] For the analysis of venture capital investments in Germany, data from transaction databases[468] are therefore used in addition to Invest Europe data. Their advantage is that the unit of observation is the individual transaction, which increases the probability that co-investments by atypical market participants[469] and non-European investors are also covered.

Figure C 4-3 provides an overview of the development of venture capital investments in Germany. Both Invest Europe and transaction data show a significant overall increase in venture capital investment between 2010 and 2020, but the increase in transaction data is much larger. However, both databases also show a significant decline in venture capital investments in 2020. Looking at the transaction data, there is a strong change in the structure of venture capital investments. Indeed, such a change would probably also be observed for other countries. The expanded data basis therefore does not allow any conclusions to be drawn as to whether Germany's weak position in the availability of venture capital relative to other countries could be improved in an international comparison. Even if venture capital investments in 2020 were underestimated by a factor of two and a half in the association data, the value for the United States would still be four times higher than that for Germany.

Fig. C 4-1 Publicly funded R&D expenditure in the business sector as a percentage of the national gross domestic product of selected countries in 2018

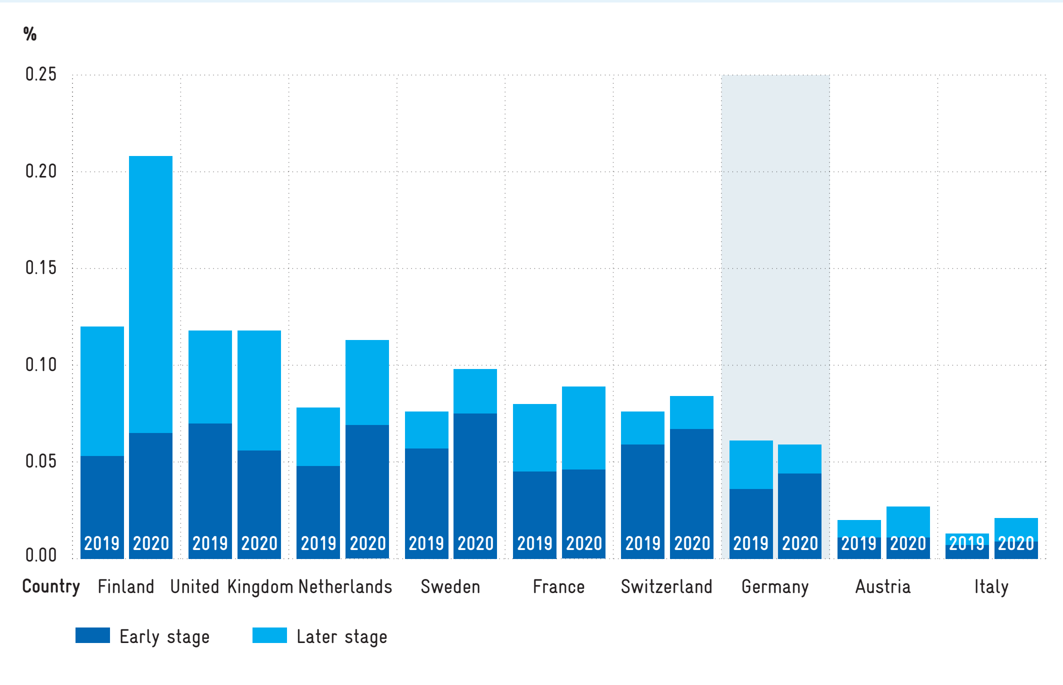
Download Data



The public funding of private-sector R&D is divided into direct R&D funding and indirect R&D funding (through tax incentives).
[1)] 2017, [2)] 2016.
Source: OECD R&D Tax Incentive Database, research March 2021.

Fig. C 4-2 Venture capital investments as a percentage of the national gross domestic product of selected countries in 2019 and 2020

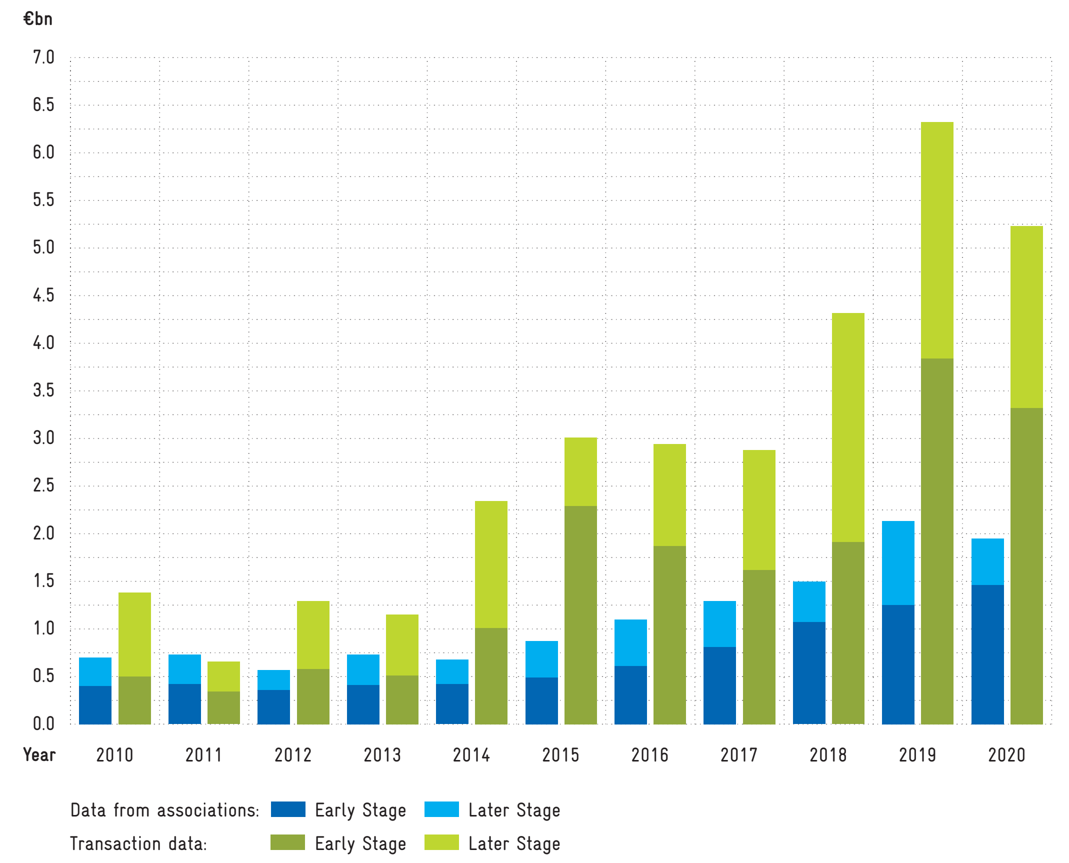
Download Data



Venture capital is defined here as temporary equity investments in young, innovative, non-listed companies.
Data for 2019 partly revised.
Investments are broken down according to the portfolio companies' head offices. Early stage comprises the seed phase and the start-up phase.
Source: Invest Europe. Calculations by ZEW in Bersch et al. (2022).

Fig. C 4-3 Venture capital investment in Germany 2010–2020 in billion euros

Download Data



Venture capital is defined here as temporary equity investments in young, innovative, non-listed companies.
Association data for 2019 slightly revised. Transaction data partly revised.
Investments are broken down according to the portfolio companies' head offices. Early stage comprises the seed phase and the start-up phase.
Source of association data: Invest Europe. Calculations by ZEW in Bersch et al. (2022).
Source of transaction data: Bureau van Dijk, Majunke. Calculations by ZEW in Bersch et al. (2022).

C 5 New Businesses

An international comparison of start-up rates, i. e. the number of start-ups in relation to the total number of companies, is only possible at the European level.[470] For this purpose, the Business Demography Statistics from Eurostat are used (C 5-1), which represent a subsection of the Structural Business Statistics (SBS) of the European Union.[471] In a comparison of the start-up rates of eight selected European countries, Germany ranked fourth in 2019 when viewed over the economy as a whole, at 9.1 percent.[472] Germany was also unable to achieve a top position in the start-up rates in R&D-intensive industry (4.2 percent, rank 6) and in knowledge-intensive services (9.6 percent, rank 5 with Italy) in 2019.

The basis for the results on business dynamics in the knowledge economy presented in figures C 5-2 to C 5-4 is an evaluation of the Mannheim Enterprise Panel (Mannheimer Unternehmenspanel, MUP) conducted by the ZEW – Leibniz Centre for European Economic Research. The MUP is the ZEW's panel data set on enterprises in Germany that has been compiled in cooperation with Creditreform, Germany's largest consumer reporting agency, since 1992.[473] The term 'enterprise' used in the MUP includes only economically active enterprises; only original start-ups are considered to be enterprise births.[474] The enterprise birth rate shown in figure C 5-2 is therefore calculated on a different data basis than in the Business Demography Statistics, so that no direct comparison is possible here.[475] This means that the values differ from the values given for Germany in figure C 5-1.

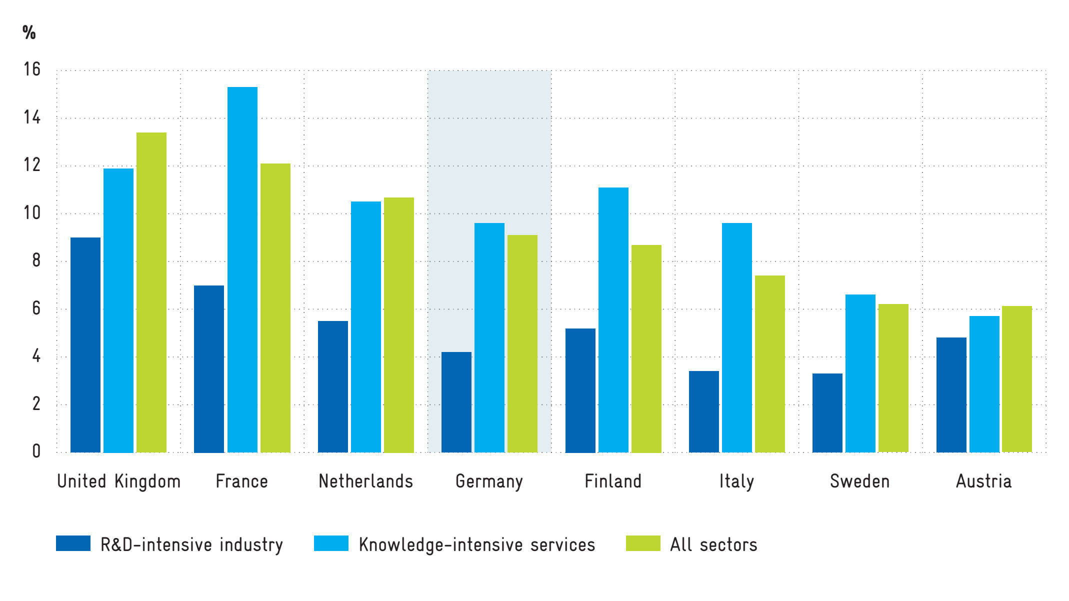
In the overall economy and in the knowledge economy, the start-up rates have been relatively constant in recent years (C 5-2).[476] Even in 2020, when the COVID-19 crisis hit the economy hard, there were no major changes in the start-up rates. In the overall economy, the start-up rate in 2020 fell slightly from the previous year from 5.1 to 5.0 percent, while in the knowledge economy it rose from 4.9 to 5.1 percent.

Like the start-up rates, the closure rates also remained stable in 2020 (C 5-3).[477] Compared to the previous year, the closure rates in the overall economy fell by 0.3 percentage points to 4.9 percent. In the knowledge economy, the rate was unchanged at 4.7 percent.

In a comparison of the Länder, Berlin had the highest start-up rates in the overall economy (6.4 percent) and in R&D-intensive industry (4.7 percent) and knowledge-intensive services (6.9 percent) in the period from 2018 to 2020 (C 5-4).[478] In R&D-intensive industry, Hamburg (4.3 percent) and Bremen (3.9 percent), the other two city states, ranked second and third. In knowledge-intensive services, Saarland (6.1 percent) and Bavaria (5.7 percent) achieved the highest start-up rates after Berlin.

Fig. C 5-1 Start-up rates in selected countries 2019 in percent

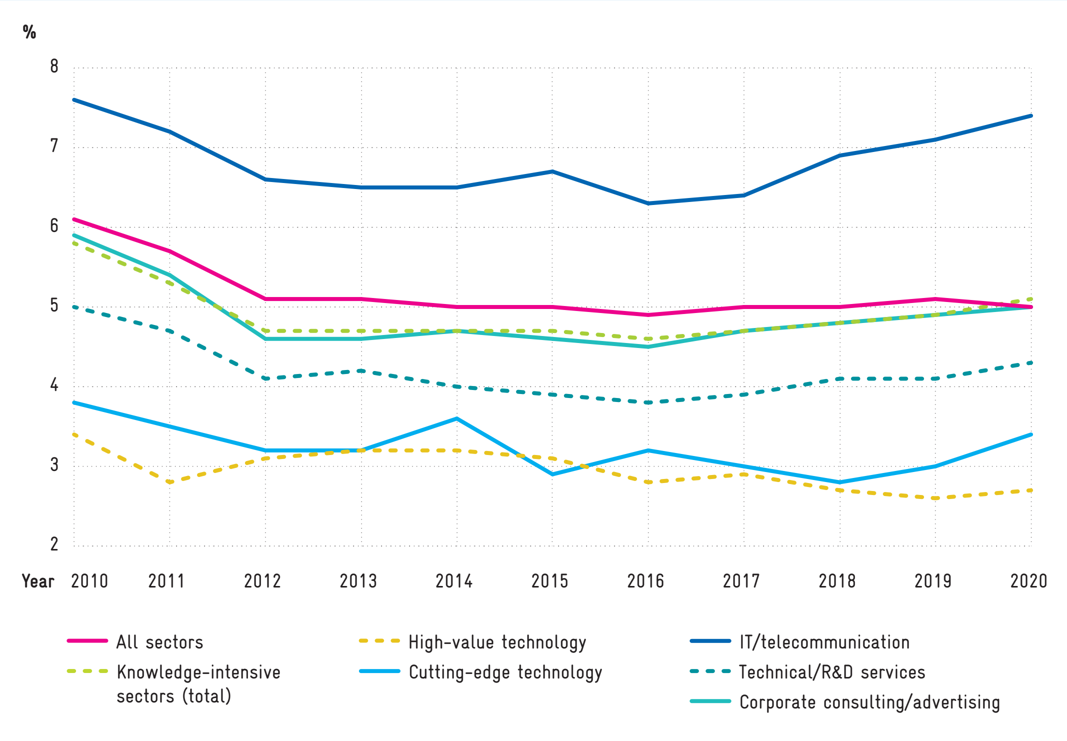
Download Data



Start-up rate: number of start-up businesses as a percentage of the total number of companies.
Source: Business Demography Statistics (Eurostat). Calculations by ZEW in Bersch et al. (2022).

Fig. C 5-2 Start-up rates in knowledge-intensive sectors in Germany 2010–2020 in percent

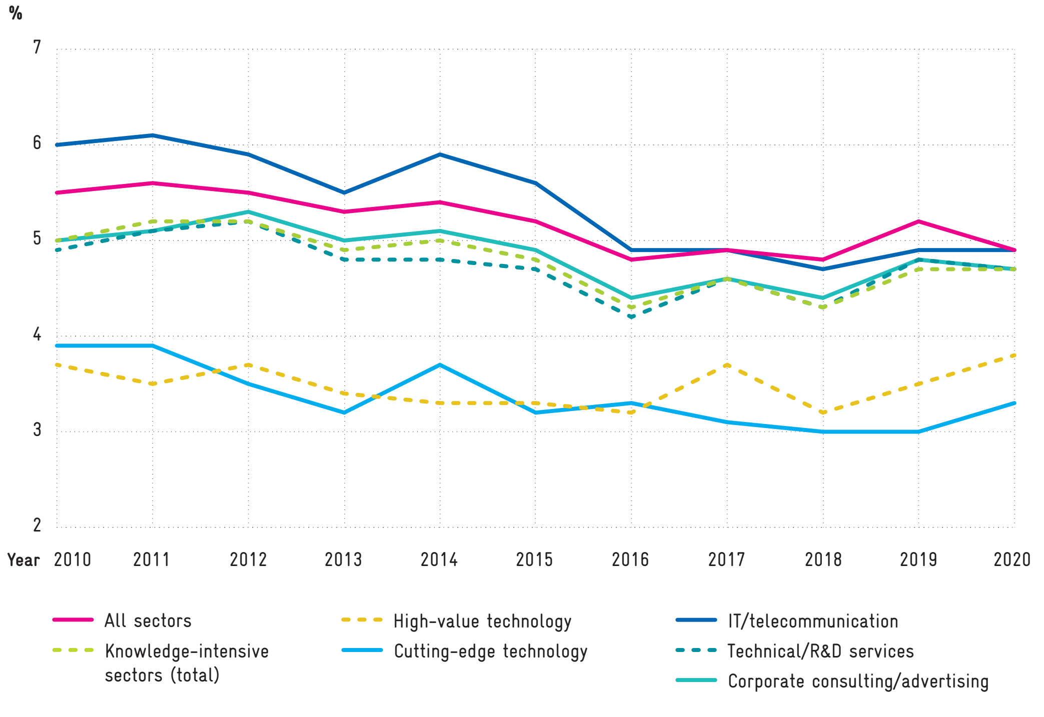
Download Data



The knowledge-intensive sectors comprise the R&D-intensive industries (high-value technology and cutting-edge technology) and knowledge-intensive services.
Start-up rate: number of start-up businesses as a percentage of the total number of companies.
All figures are provisional.
Source: Mannheim Enterprise Panel. Calculations by ZEW in Bersch et al. (2022).

Fig. C 5-3 Closure rates in knowledge-intensive sectors in Germany 2010–2020 in percent

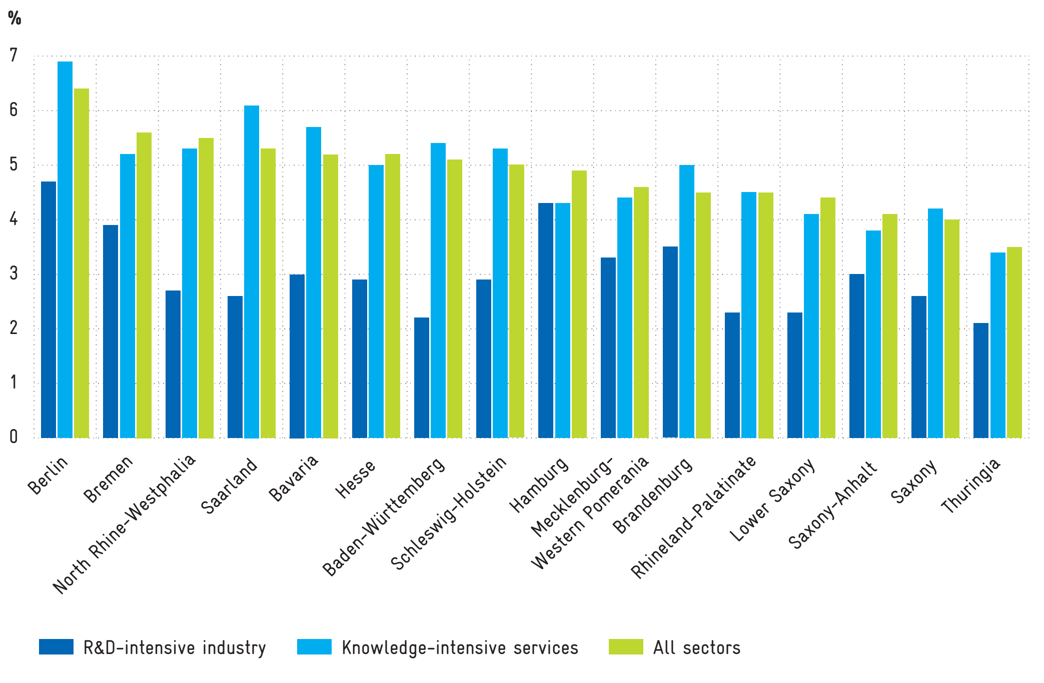
Download Data



The knowledge-intensive sectors comprise the R&D-intensive industries (high-value technology and cutting-edge technology) and knowledge-intensive services.
Closure rate: number of companies that close during a year as a percentage of all companies.
All figures are provisional.
Source: Mannheim Enterprise Panel. Calculations by ZEW in Bersch et al. (2022).

Fig. C 5-4 Start-up rates by Länder 2018–2020 in percent

Download Data



Start-up rate: number of start-up businesses as a percentage of the total number of companies.
All figures are provisional.
Source: Mannheim Enterprise Panel. Calculations by ZEW in Bersch et al. (2022).

C 6 Patents[479]

The number of transnational patent applications is a measure of the innovative activity of an economy. The total number of annual patent applications in the countries under consideration almost tripled in the period from 1997 to 2019. Since the mid-2000s, however, Germany's transnational patent applications have stagnated, as have those of other European economies such as the United Kingdom, Sweden and Switzerland (C 6-1). In contrast, China and South Korea in particular have shown high growth rates during this period. After Germany and Japan, China also overtook the USA for the first time in 2019 and now has the highest number of transnational patent applications.

While China leads in absolute applications in 2019, it continues to lag well behind the large European and Asian industrialized nations in terms of patent intensity (patent applications per million employees) (C 6-2). Here, Switzerland, Sweden and Japan are at the top, followed by South Korea, Finland and Germany. The leading economies have patent intensities that are higher than China's by a factor of around 10. However, in the development of patent intensity in the years 2009 to 2019, China recorded by far the highest dynamics of all countries considered.

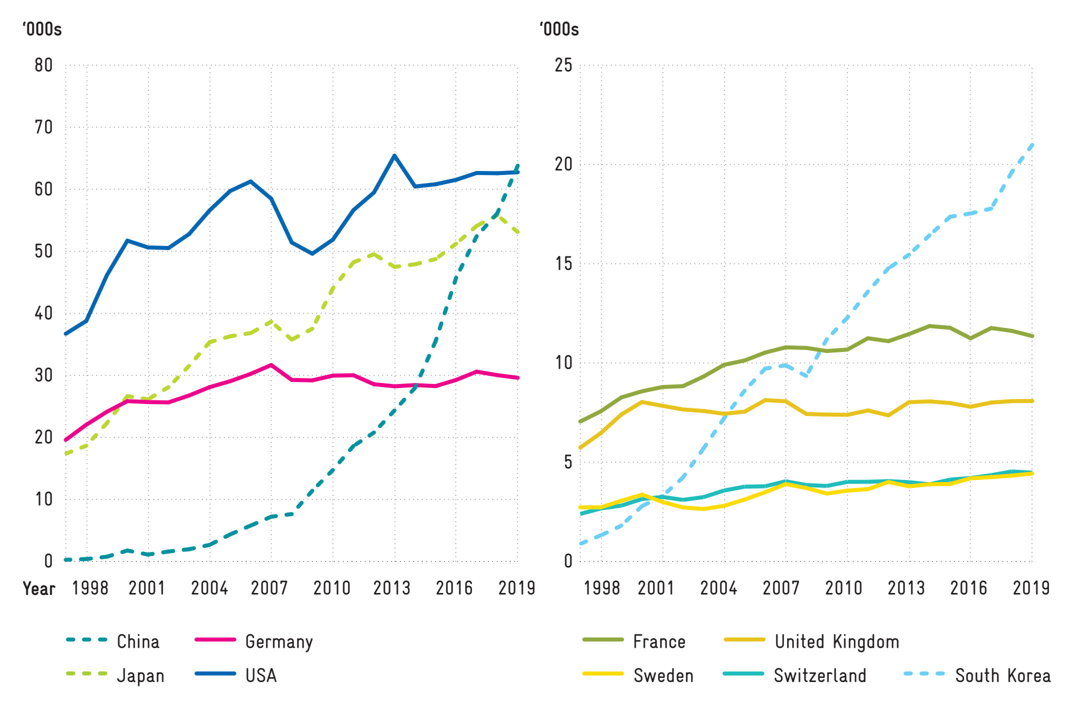
Further conclusions about a country's technological performance can be drawn from patent activities in R&D-intensive technologies. This area includes industry sectors that invest more than 3 percent of their turnover in R&D (R&D intensity). R&D-intensive technology comprises the areas of high-value technology (R&D intensity between 3 and 9 percent) and cutting-edge technology (R&D intensity higher than 9 percent).

An international comparison reveals Germany's clear and stable specialization in high-value technology (C 6-3), which can be explained by Germany's traditional strengths in the automotive industry, mechanical engineering and the chemical industry. Germany records the highest value of the comparison group here.

In contrast, China, Sweden and the USA specialize in cutting-edge technology (C 6-4), an area in which Germany, like Japan, underperforms. These specializations reflect the technological orientation of the economies under consideration and are subject to only minor fluctuations during the observation period.

Fig. C 6-1 Number of transnational patent applications in selected countries 1997–2019

Download Data



Transnational patent applications comprise applications in patent families with at least one application to the World Intellectual Property Organization (WIPO) via the Patent Cooperation Treaty (PCT) or one application to the European Patent Office (EPO).
Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler and Rothengatter (2022).

Tab. C 6-2 Number, intensity and growth rates of transnational patent applications in the field of R&D-intensive technology in selected countries in 2019

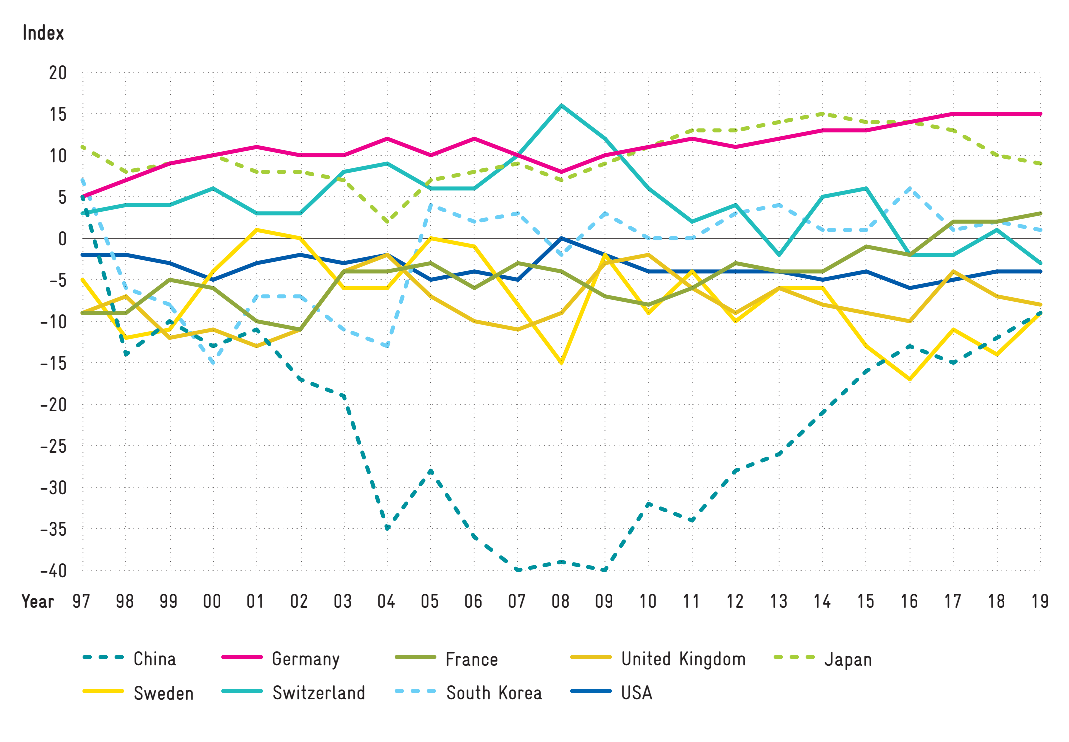
Download Data

	Number*	Intensity*	Intensity in R&D-intensive technology	Growth (2009=100)*	Growth in R&D-intensive technology (2009=100)
Total	306,087			152	152
China	63,805	83	59	560	527
Germany	29,608	698	402	101	104
EU-28	79,331	348	197	110	111
Finland	1,893	738	419	103	100
France	11,356	418	247	107	108
United Kingdom	8,085	247	141	109	106
Italy	6,028	258	125	109	107
Japan	53,115	790	456	142	127
Canada	3,624	190	119	102	100
Netherlands	5,004	557	286	127	123
Sweden	4,428	863	593	129	133
Switzerland	4,471	950	472	118	104
South Korea	20,983	774	484	187	175
USA	62,748	398	263	126	128

The R&D-intensive technology sector comprises industries that invest more than 3 percent of their turnover in research and development. Intensity is calculated as the number of patents per million gainfully employed persons.
* Figures refer to all industries.
Source: EPO (PATSTAT), OECD (MSTI), World Bank. Calculations by Fraunhofer ISI in Neuhäusler and Rothengatter (2022).

Download Data

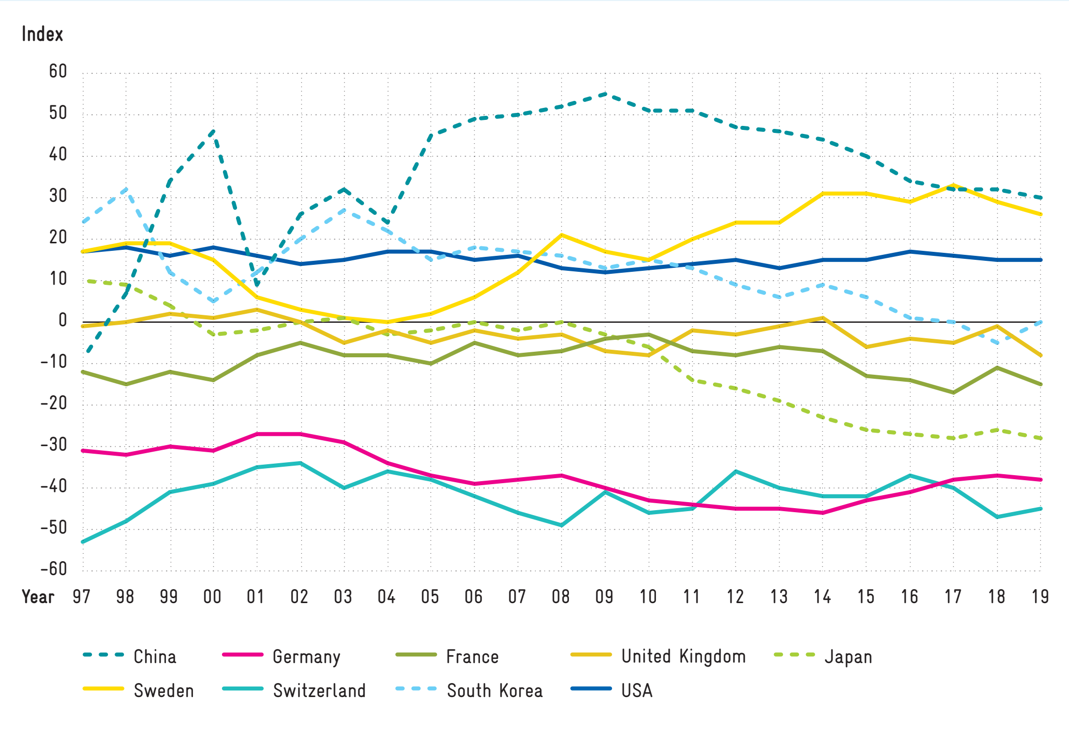
Fig. C 6-3 Specialization index in selected countries in the field of high-value technology 1997–2019



The specialization index is calculated based on all transnational patent applications worldwide. Positive or negative values indicate whether the surveyed country's level of activity in a given field is disproportionately high or low compared to the global average.
Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler and Rothengatter (2022).

Download Data

Fig. C 6-4 Specialization index in selected countries in the field of cutting-edge technology 1997–2019



The specialization index is calculated based on all transnational patent applications worldwide. Positive or negative values indicate whether the surveyed country's level of activity in a given field is disproportionately high or low compared to the global average.
Source: EPO (PATSTAT). Calculations by Fraunhofer ISI in Neuhäusler and Rothengatter (2022).

C 7 Scientific Publications[480]

A large part of new technologies and services is based on developments and results from science. Bibliometric indicators and metrics are therefore regularly used as a measure of scientific performance to assess the performance of a research and science system in quantitative and qualitative terms. The bibliometric database Web of Science records publications in scientific journals and citations of these publications worldwide. The indication of the location of the scientists' research institutions makes it possible to assign individual publications to countries. If several authors from different countries are involved in a publication, they are included in the calculations in a fractionated counting method. Indicators regarding the quantity and quality of scientific publications can be used to assess the performance of a research and science system.

The publication shares of selected countries and regions in all publications in the Web of Science (C 7-1) show significant changes for the comparative view of the years 2010 and 2020. Most countries, including the large western European countries of Germany, France and the UK, as well as the USA, have lost publication shares. The German publication share has fallen from 5.2 to 3.9 percent, the British from 5.4 to 4.1 percent, the French from 3.7 to 2.4 percent and the US-American from 23.3 to 17.1 percent. This contrasts with an enormous increase in China's share of publications from 9.8 to 23.1 percent.

The international alignment (IA) of selected countries and regions in publications in the Web of Science (C 7-2) is an indicator of the relative quality of scientific publications. Germany's index score was 8.5 in 2018, down from 15.4 in 2010. Publications by authors from Germany have thus relatively lost quality. The publication quality of almost all countries that performed above average in 2010 has declined in relative terms. China was again able to improve its relative publication quality, achieving an index value of 7.1 for 2018.

The scientific regard (SR) indicator for publications in the Web of Science (C 7-3) shows that the index value for articles from Germany has fallen from 7.3 to 0.1 during the observation period. Articles from Germany were thus cited on average almost as frequently in 2018 as other articles in the journals in which they appeared. In 2010, on the other hand, German articles were still cited with above-average frequency compared to other articles in the respective journal. This weakening trend is evident in most countries that had an above-average index value for 2010. In contrast, Italy, China and India achieved significant improvements to an above-average index score.

Fig. C 7-1 Shares of all publications from selected countries and regions in 2010 and 2020 in percent

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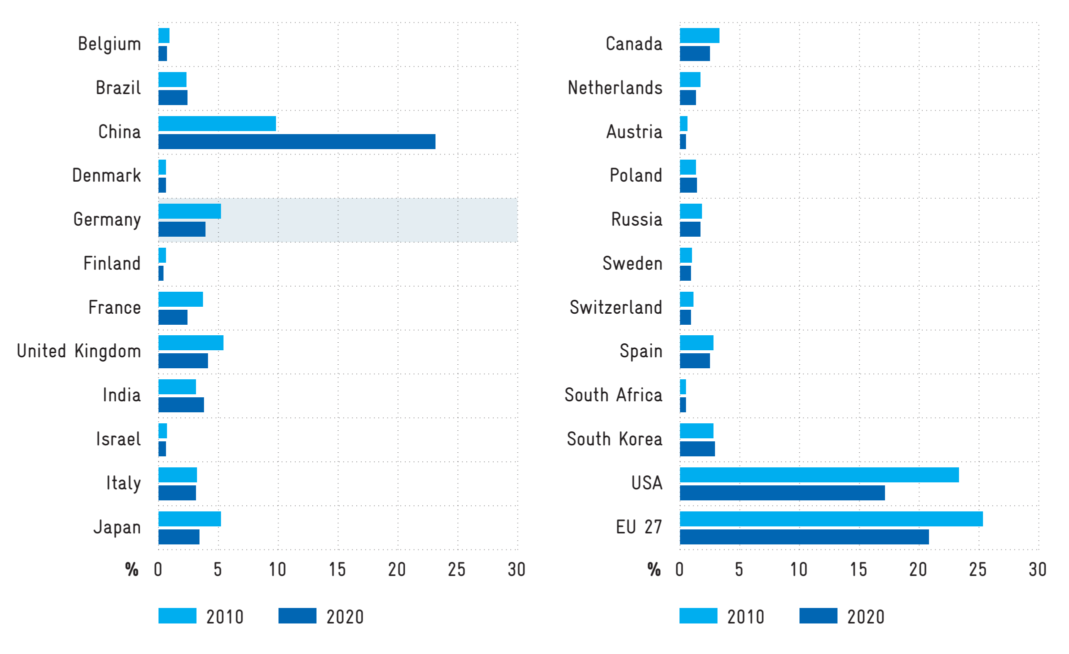
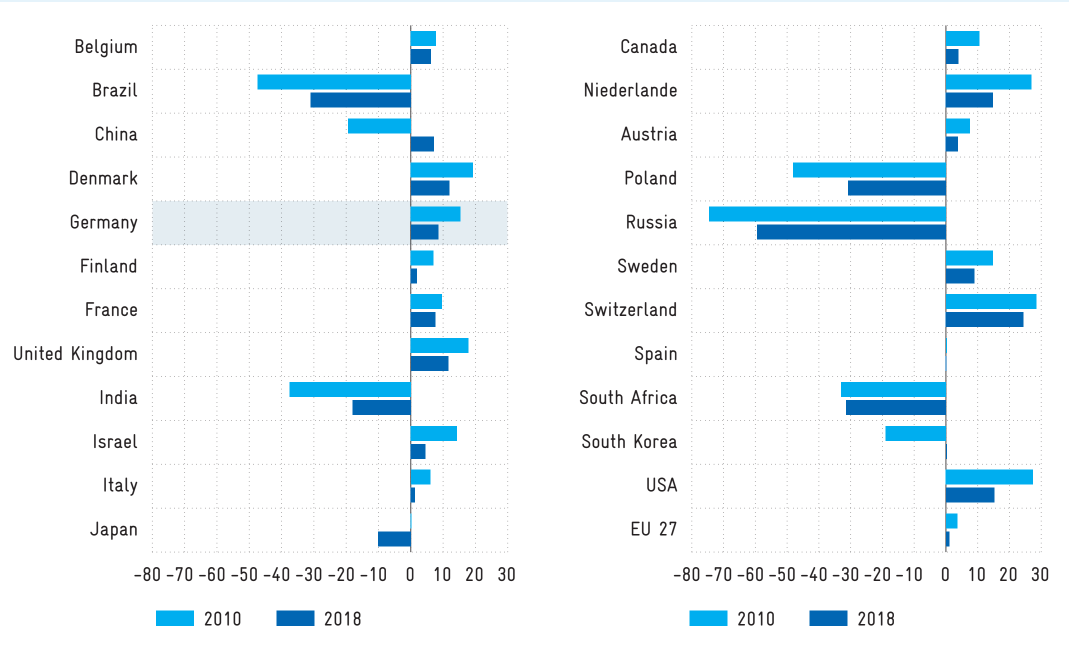


Fractional counting.
Source: Web of Science. Research and calculations by DZHW in Stephen und Stahlschmidt (2022).

Fig. C 7-2 International alignment (IA) of publications from selected countries and regions in 2010 and 2018 (index values)

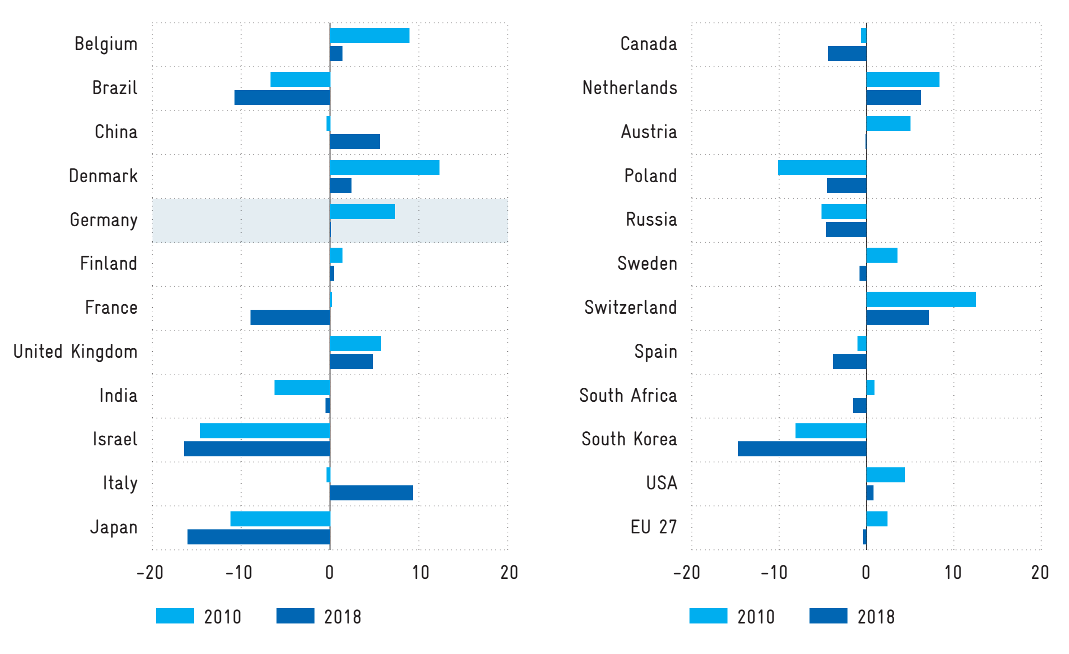
Download Data



The IA index indicates whether a country's authors publish in internationally more highly recognized or less highly recognized journals relative to the world average. Positive or negative values indicate an above-average or below-average IA.
Fractional counting.
Source: Web of Science. Research and calculations by DZHW in Stephen und Stahlschmidt (2022).

Download Data

Fig. C 7-3 Scientific regard (SR) of publications from selected countries and regions in 2010 and 2018 (index values)



The SR index indicates whether a country's articles are cited on average more frequently or more seldom than other articles in the journals in which they appeared. Positive or negative values indicate an above-average or below-average scientific regard. The index is calculated without self-citations.
Fractional counting.
Source: Web of Science. Research and calculations by DZHW in Stephen und Stahlschmidt (2022).

C 8 Production, Value Added and Employment[481]

The specialization pattern of a country in foreign trade can be measured with the help of the RCA indicator.[482] It records the export/import ratio of a product group in relation to the export/import ratio of the processed industrial goods as a whole. As in recent years, Germany had a comparative advantage in trade in R&D-intensive goods in 2020 (C 8-1). R&D-intensive goods consist of high-value technology goods and cutting-edge technology goods. However, a closer look at these two groups of goods shows that Germany's comparative advantage was only positive for trade in high-value technology goods, while it was negative for trade in cutting-edge technology goods. France, the United Kingdom, Switzerland, South Korea and the USA recorded positive values of the RCA indicator in the area of cutting-edge technology; China and Japan showed a negative RCA indicator here over the entire period under review. Sweden has recorded negative values since 2010.

The share of research-intensive and knowledge-intensive industries in a country's value added allows conclusions to be drawn about its technological performance in an international comparison (C 8-2). The development in Germany has been characterized by a decreasing dynamic for several years. The share of value added has increased only slightly since around 2015 and has even decreased at the current margin. While Germany had the highest share of value added in the area of high-value technology relative to the countries considered in 2019 (8.7 percent), in the area of cutting-edge technology Germany was well behind the leaders Switzerland (9.5 percent) and South Korea (9.2 percent) at 2.8 percent. Knowledge-intensive services contributed significantly more to national value added than research-intensive industries in all countries considered. Yet with a value added share of 25.5 percent, they played a smaller role in Germany in 2019 compared to the other countries considered (exception: South Korea).

Gross value added has risen continuously in Germany since 2009 (C 8-3). At 3.6 percent, growth in knowledge-intensive services was higher in 2019 than in the previous year (3.2 percent). In the knowledge-intensive manufacturing sector, on the other hand, the increase in value added in 2019 was 0.4 percent, lower than in 2018 (1.1 percent).

The increase in employment subject to social security contributions in various commercial sectors of the economy in Germany between 2010 and 2020 is mainly due to the service sector (C 8-4). In the knowledge-intensive services, employment subject to social security contributions increased by 28.3 percent during this period. In the knowledge-intensive manufacturing sector, employment subject to social security contributions increased by 13.6 percent.

Download Data

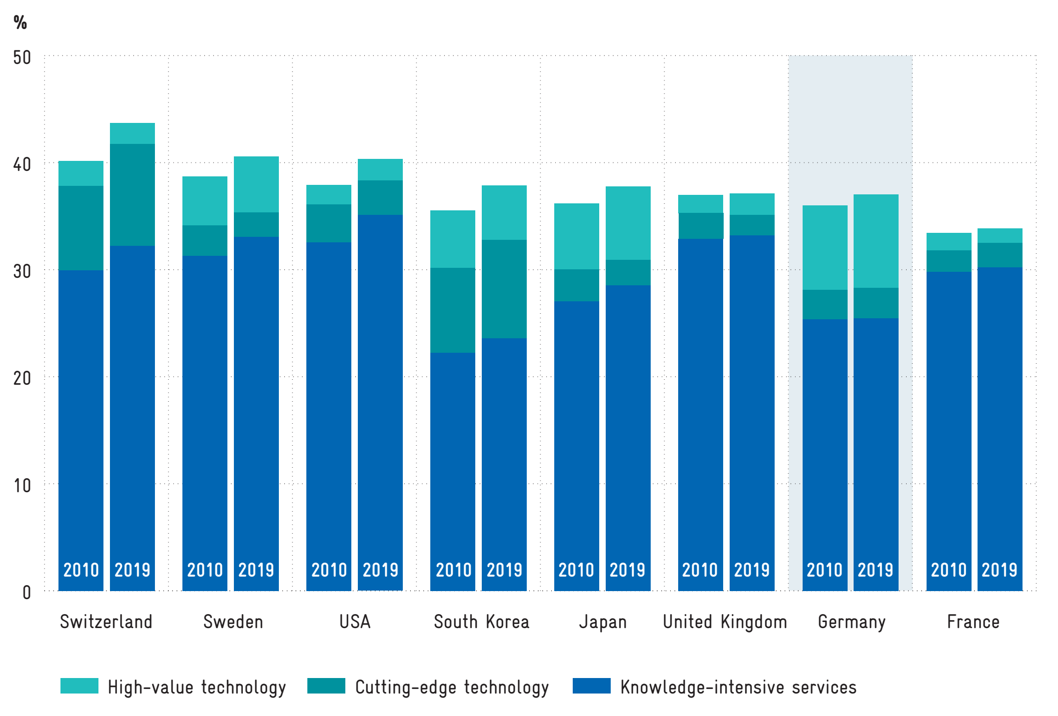
Tab. C 8-1 Revealed comparative advantage (RCA) of selected countries in foreign trade in R&D-intensive goods 2005–2020 (index values)

Year	China*	Germany	France	United Kingdom	Japan	Sweden	Switzerland	South Korea	USA
				R&D-intensive goods					
2005	–29	10	7	14	42	–1	18	17	17
2010	–27	12	6	11	33	–6	22	19	1
2015	–27	13	5	3	31	–5	28	13	2
2020	–29	8	3	20	26	–1	38	8	–1
				High-value technology goods					
2005	0	27	6	4	75	–2	24	11	–5
2010	–16	30	–2	15	61	–3	21	7	–10
2015	–3	27	–6	1	63	1	21	13	–14
2020	4	19	–6	18	62	7	24	1	–11
				Cutting-edge technology goods					
2005	–53	–34	8	33	–14	1	4	24	55
2010	–35	–35	20	1	–22	–11	25	33	22
2015	–46	–23	21	8	–35	–22	41	12	27
2020	–54	–19	20	23	–44	–25	66	15	14

R&D-intensive goods comprise high-value technology goods and cutting-edge technology goods.
A positive RCA value means that the exp./imp. ratio for this product group is higher than for manufactured industrial goods as a whole.
* incl. Hong Kong.
Source: UN COMTRADE database, research August 2021. Calculations and estimates by CWS in Schiersch et al. (2022).

Download Data

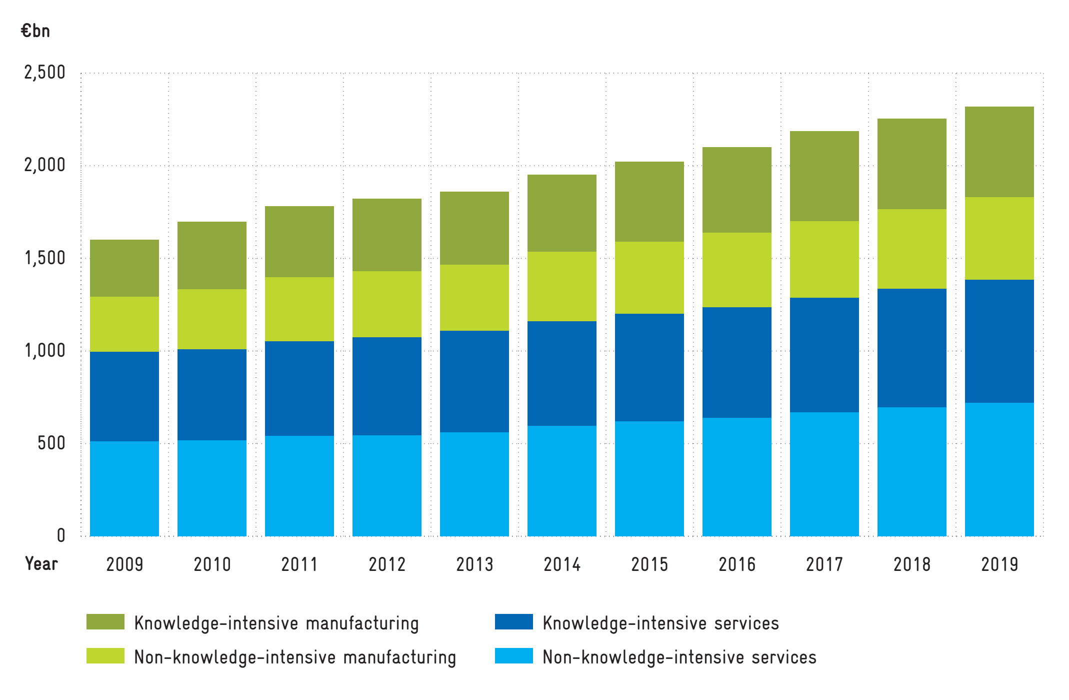
Fig. C 8-2 R&D-intensive industries and knowledge-intensive services in selected countries as a percentage of value added in 2010 and 2019



R&D-intensive industries (high-value technology and cutting-edge technology) have an above-average R&D intensity. Knowledge-intensive services are characterized by an above-average proportion of employees with tertiary education qualifications.
Source: OECD-NA, OECD-STAN, OECD-SBS, Eurostat-NA, Eurostat-SBS, EU KLEMS. Calculations and estimates by DIW Berlin in Schiersch et al. (2022).

Fig. C 8-3 Gross value added in different industrial business sectors in Germany 2009–2019 in billion euros

Download Data



Gross value added is the difference between the total value of all goods and services produced and the intermediate inputs received from other companies for their production.
Industrial business sectors excluding agriculture, forestry, fisheries, public administration and services, real estate and housing, education, private households, social insurance, religious and other organizations, associations and trade unions.
Source: Federal Statistical Office, Fachserie 18, Reihe 1.4, calculation status August 2021. Calculations by CWS in Schiersch et al. (2022).

Fig. C 8-4 Number of employees subject to social security contributions in different industrial business sectors in Germany 2010–2020 in millions

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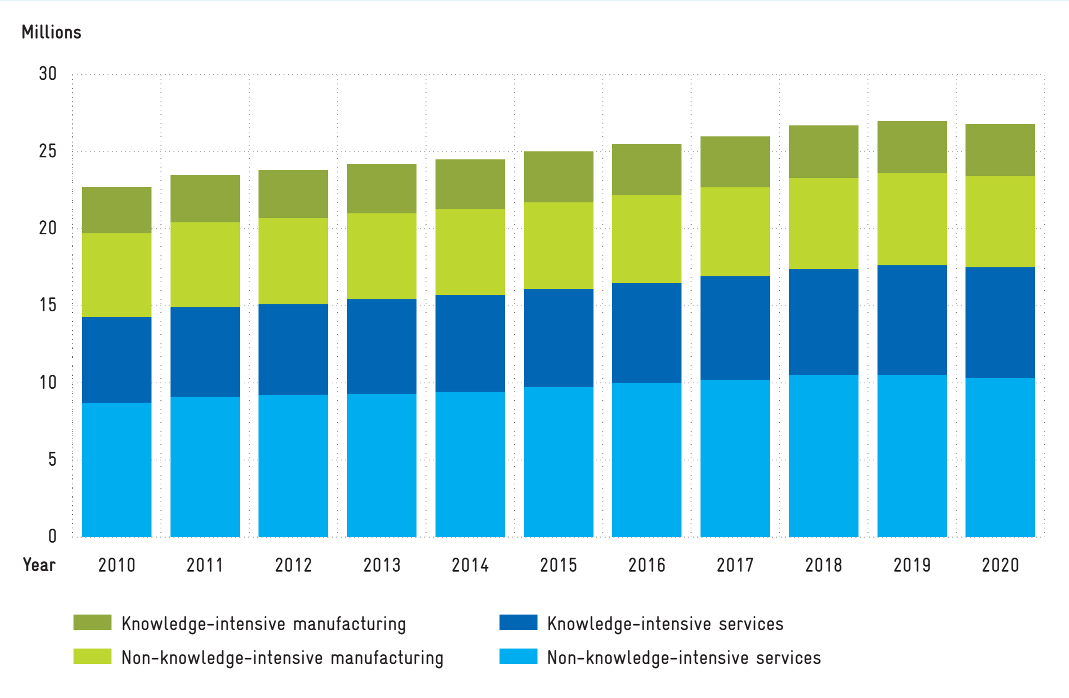

Industrial business sectors excluding agriculture, forestry, fisheries, public administration and services, real estate and housing, education, private households, social insurance, religious and other organizations, associations and trade unions.
Source: Federal Employment Agency. Calculations by CWS in Schiersch et al. (2022).

D

LISTS

Contents

D 1 List of Figures, Tables and Boxes

D 2 List of Abbreviations

5G	Fifth Generation of Mobile Telephony
AI	Artificial Intelligence
AMIA	American Medical Informatics Association
API	Application Programming Interface
B2B	Business-to-Business
B2C	Business-to-Consumer
BA	Federal Employment Agency (Bundesagentur für Arbeit)
BAföG	Federal Training Assistance Act (Bundesausbildungsförderungsgesetz)
BEHG	Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz)
BEV	Battery Electric Vehicle
BfArM	Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMDV	Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr)
BMF	Federal Ministry of Finance (Bundesministerium der Finanzen)
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur)
BMWi	Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie)
BMWK	Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz)
BSI	Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik)
CCfD	Carbon Contracts for Difference
CIS	Community Innovation Survey
CO_2	Carbon dioxide
CPC	Cooperative Patent Classification
CWS	Center for Economic Policy Studies (Center für Wirtschaftspolitische Studien)
DAC	Direct Air Capture
DATI	German Agency for Transfer and Innovation (Deutsche Agentur für Transfer und Innovation)
DESI	Digital Economy and Society Index
DGA	Data Governance Act

LISTS

DICE .... Düsseldorf Institute for Competition Economics
DiGA .... Digital Health Applications (Digitale Gesundheitsanwendungen)
DIH .... Data Intelligence Hub
DMA .... Digital Markets Act
DMP .... Dossier Médical Partagé
DNG .... Act on the Use of Public Sector Data (Datennutzungsgesetz)
DPMA .... German Patent and Trade Mark Office (Deutsches Patent- und Markenamt)
DSS .... Dynamic Spectrum Sharing
DVG .... Digital Care Act (Digitale-Versorgung-Gesetz)
DZHW-ICE German Centre for Higher Education Research and Science Studies – Information, Controlling, Decision (Deutsches Zentrum für Hochschul- und Wissenschaftsforschung GmbH – Information, Controlling, Entscheidung)
EEG .... Renewable Energies Act (Erneuerbare-Energien-Gesetz)
EFI .... Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation)
EGovG .... E-Government Act (E-Government-Gesetz)
EIF .... European Investment Fund
ELGA .... Electronic Health Record (Elektronische Gesundheitsakte)
EPA .... European Patent Office (Europäisches Patentamt)
EPO .... European Patent Office
ePR .... Electronic Patient Record
Eq. .... Equivalent
ERP .... European Recovery Program
ERT .... European Round Table for Industry
ESG .... European Standards and Guidelines
EU .... European Union
EU ETS .... European Union Emissions Trading System
EU KLEMS .... EU Level Analysis of Capital, Labour, Energy, Materials and Service Inputs
EU 27 .... Member States of the European Union
Eurostat .... Statistical Office of the European Union
Eurostat-NA .... Eurostat National Accounts
Eurostat-SBS .... Eurostat Structural Business Statistics
EXIST .... EXIST – University-Based Start-Ups (Existenzgründungen aus der Wissenschaft)
FAIR .... Findable, Accessible, Interoperable, Reusable
FCEV .... Fuel Cell Electric Vehicle
Gbit/s .... Gigabit/second
GDP .... Gross Domestic Product
GDPR .... General Data Protection Regulation
GFF .... German Future Fund
GHG .... Greenhouse Gases
GKV .... Statutory Health Insurance Fund (Gesetzliche Krankenversicherung)
GPT .... General Purpose Technology
GSB .... Government Site Builder
GWB .... Act Against Restraints of Competition (Gesetz gegen Wettbewerbsbeschränkungen)
HEV .... Hybrid Electric Vehicle
HG .... Budget Act (Haushaltsgesetz)

HTS .... High-Tech Strategy
IAB .... Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung der Bundesagentur für Arbeit)
ICEV .... Internal Combustion Engine Vehicle
ICT .... Information and Communication Technology
IDC .... International Data Corporation
IoT .... Internet of Things
IPC .... International Patent Classification
IPCC .... Intergovernmental Panel on Climate Change
IPCEI .... Important Project of Common European Interest
ISCED .... International Standard Classification of Education
ISI .... Fraunhofer Institute for Systems and Innovation Research (Fraunhofer Institut für System- und Innovationsforschung)
ISO .... International Organization for Standardization
IT .... Information Technology
IW .... German Economic Institute (Institut der deutschen Wirtschaft Köln e. V.)
KBA .... Federal Motor Transport Authority (Kraftfahrt-Bundesamt)
KET .... Key Enabling Technology
KfW .... Kreditanstalt für Wiederaufbau
KIM .... Communication in Healthcare (Kommunikation im Medizinwesen)
KMK .... Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (Kultusministerkonferenz)
LFP .... Lithium Ferro Phosphate
LNMO .... Lithium Nickel Manganese Oxide
LOHC .... Liquid Organic Hydrogen Carriers
MII .... Medical Informatics Initiative (Medizininformatik-Initiative)
MIP .... Mannheim Innovation Panel (Mannheimer Innovationspanel)
MPT .... Motorized Private Transport
MSTI .... Main Science and Technology Indicators
MUP .... Mannheim Enterprise Panel (Mannheimer Unternehmenspanel)
NACE .... Nomenclature Statistique des Activités Économiques dans la Communauté Européenne
n.e.c. .... not elsewhere classified
NFDI .... National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur)
NKR .... National Regulatory Control Council (Nationaler Normenkontrollrat)
NMC .... Nickel Mangan Cobalt Oxide
NO_x .... Nitrogen Oxides
NUB .... New Examination and Treatment Method (Neue Untersuchungs- und Behandlungsmethode)
OECD .... Organization for Economic Co-operation and Development
OECD-NA .... OECD National Accounts
OECD-SBS .... OECD Structural Business Statistics

OECD-STAN	OECD Structural Analysis Database
OZG	Online Access Act (Onlinezugangsgesetz)
P2B	Platform-to-Business
PATSTAT	Patent Statistical Database
PBefG	Passenger Transport Act (Personenbeförderungsgesetz)
PCT	Patent Cooperation Treaty
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
R&D	Research and Development
R&I	Research and Innovation
RCA	Revealed Comparative Advantage
RoW	Rest of the World
RPS	Relative Patent Share
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus Type 2
SBS	Structural Business Statistics
SDG	Sustainable Development Goal
SME	Small and Medium-sized Enterprises
SNOMED-CT	Systematized Nomenclature of Medicine Clinical Terms
SprinD	Federal Agency for Disruptive Innovation (Bundesagentur für Sprunginnovationen)
SR	Scientific Regard
STEM	Science, Technology, Engineering, and Mathematics
SV	Stifterverband für die Deutsche Wissenschaft e. V.
SVR	German Council of Economic Experts (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung)
Syn.	Synthetic
TCO	Total Cost of Ownership
TI	Telematics Infrastructure
TU	Technical University
UAS	University of Applied Sciences (Hochschule für Angewandte Wissenschaften)
UBA	German Federal Environment Agency (Umweltbundesamt)
UN Comtrade	United Nations Commodity and Trade
USPTO	United States Patent and Trademark Office
VDE	German Association for Electrical, Electronic & Information Technologies (Verband der Elektrotechnik Elektronik Informationstechnik e. V.)
VDI	Association of German Engineers (Verein Deutscher Ingenieure e. V.)
VDMA	German Mechanical and Plant Engineering Association (Verband Deutscher Maschinen- und Anlagenbau e. V.)
VDV	Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen e. V.)
VZBV	Federation of German Consumer Organisations (Verbraucherzentrale Bundesverband)
WIPO	World Intellectual Property Organisation
WoS	Web of Science
WZ	Business Sectors (Wirtschaftszweige)
ZEW	ZEW – Leibniz Centre for European Economic Research (ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung GmbH Mannheim)

D 3 Glossary

Artificial intelligence (AI)
A distinction is made between symbolic and neural AI. Symbolic AI is based on the concept of developing rules that allow a conclusion to be drawn from input values. In contrast, in neural AI these rules result from a matching of input values and inferences. Thus, symbolic AI is a deductive system, while neural AI is an inductive system.

Autonomous driving
Autonomous driving means the autonomous, goal-directed driving of a vehicle in real traffic, without the intervention of a person on site.

Big data
The term big data summarizes technological developments in the field of data storage and processing that make it possible to integrate ever larger volumes of data in a wide variety of formats and to process them in an ever shorter time. Big data offers the opportunity to continue to control the exponentially increasing data volumes caused by the increasing ubiquity ('omnipresence') of information and communication technologies (ICT) and, above all, to use them in a value-creating way.

Biomass
Biomass consists of substances that are produced by or bound in living organisms. Biomass in the sense of energy technology is when animal and plant products can be used to generate heating energy, electrical energy and fuels.

Bundled on-demand transport
According to the Passenger Transport Act, bundled on-demand transport is the transport of passengers by passenger vehicles in which several transport requests along similar routes are carried out in a bundle.

Charging infrastructure
This refers to the infrastructures for charging electric vehicles and includes, among other things, the construction and expansion of fast charging stations on the motorway with connection to a medium-voltage grid as well as e-filling stations and private charging stations.

Club good
A club good is a good characterized by non-rivalry in use and excludability from use.

CO_2 border adjustment
A CO_2 border adjustment is intended to prevent the relocation of CO_2-intensive production abroad. For this purpose, CO_2-intensive imports are subject to a CO_2 tax or emission certificates must be purchased for them. The amount of the tax or the number of certificates depends on the emissions generated during production. The competitiveness of low-CO_2 domestic industry can be maintained in this way.

Community Innovation Survey (CIS)
The Community Innovation Survey (CIS) is an innovation survey in the European Union that has been conducted regularly since 1993 according to a uniform methodological standard.

Comparative advantages
Comparative advantages determine the involvement of an economy in foreign trade. The advantageousness of trade depends on the relative production costs of the goods. If economy A must forego fewer units of another good for the production of a good than another economy, then economy A has a comparative advantage in the production of this good.

Cutting-edge technology
Cutting-edge technology goods are those R&D-intensive goods (cf. there) for whose production more than 9 percent of turnover is spent on research and development on an annual average.

Data intermediaries
Data intermediaries are providers who offer data sharing services, e.g. between companies. Such

services include, for example, the establishment of platforms (data marketplaces) for the exchange or joint exploitation of data or the establishment of the technical infrastructure for the networking of data holders and users.

Data portability
Data portability in the context of digital platforms describes the possibility for stakeholders to transfer their data from one platform to another.

Data spaces
Data spaces are shared and trusted transaction spaces through which data are provided and shared decentrally by different groups of stakeholders.

Debt brake
The debt brake is the term used to describe the regulation enshrined in Article 109 of the Basic Law, which stipulates that the budgets of the Federal Government and the Länder must in principle be balanced without revenues from loans.

Direct air capture (DAC)
Direct air capture refers to the extraction and capture of CO_2 (and possibly other greenhouse gases) directly from the atmosphere with the aim of storing it or making it usable for further applications. In particular, this process should make it possible in the future to reduce the amount of CO_2 from diffuse emission sources.

Disruptive innovations
Disruptive innovations are innovations that bring about far-reaching change in markets, organizations and societies and open great potential for value creation.

Early stage
Early stage describes the financing of the early development of a company, starting with the financing of research and product conception (seed phase), through the founding of the company, to the start of operational business activities including product development and initial marketing (start-up phase). The seed phase is limited to research and development (R&D) up to the maturity and first implementation of a business idea with a prototype, while within the start-up phase a business plan is drafted and the start of production and product marketing take place.

Economies of scale
Economies of scale refer to cost advantages that are expressed in the fact that unit or average costs decrease as production volume increases. These effects occur, for example, in production processes that are characterized by high fixed costs but low duplication costs or variable costs.

Economies of scope
We speak of economies of scope when there are mutual dependencies between decision-making areas (e. g. activities in different markets) that have an impact on overall success.

EEG levy
The Renewable Energies Act (Erneuerbare-Energien-Gesetz, EEG) regulates the EEG levy, which serves to finance the expansion of renewable energies. To cover the shortfall resulting from the difference between the revenue from the sale of electricity from renewable energies (RES-E) on the stock exchange and the expenditure due to the legally fixed feed-in tariff (cf. there), the transmission system operators levy a monetary amount per kilowatt hour of electricity, the so-called EEG levy, on each electricity supply company that supplies end consumers.

EXIST Programme
With the programme EXIST – University Based Start-Ups (Existenzgründungen aus der Wirtschaft), launched in 1998, the BMWK (formerly BMWi) promotes start-up activities at universities and non-university research institutions.

Federal Training Assistance Act (BAföG)
The Federal Training Assistance Act (Bundesausbildungsförderungsgesetz, BAföG) regulates the individual funding of the training of pupils and students by the public sector.

Feed-in tariff
The feed-in tariff is a legally fixed payment that electricity producers receive for feeding electricity from renewable energy sources (RES-E) into the public grid.

Foresight processes
Foresight processes are used for longer-term foresight regarding technological and societal changes.

Frascati Manual
The OECD's so-called Frascati Manual contains methodological guidelines for the collection and analysis of data on research and development. In 1963, experts from the OECD met for the first time with members of the NESTI group (National Experts on Science and Technology Indicators) in Frascati, Italy, to define essential terms such as research and development. The result of these discussions became known as the first Frascati Manual. Since then, the Frascati Manual has been revised several times. The most recent edition dates from 2015.

Fuel cells
Fuel cells convert the energy from the chemical reaction of e.g. hydrogen with oxygen into electrical energy.

Future Fund
To boost the venture capital market in Germany and improve the funding situation of start-ups (cf. there), the Federal Government created the conditions for the so-called Future Fund with the adoption of the Budget Act 2021. This is particularly aimed at improving the funding options in the capital-intensive scaling phase of start-ups. So far, the modular Future Fund comprises the ERP/Future Fund Growth Facility, the GFF/EIF Growth Facility, the DeepTech Future Fund and the Growth Fund.

Future technology
A future technology is a technology that has a high relevance for the market and has a high growth potential for the future.

GAIA-X
The GAIA-X project initiated by the BMWi in October 2019 is a European platform ecosystem that ensures uniform technical interfaces and standards for data protection and IT security, on the basis of which actors can exchange data securely and network internationally.

Governance
Governance refers to the management and regulation system in the sense of structures (organizational and operational structure) of a political-social unit such as the state, administration, municipality, private and public organizations. The term is often also used in the sense of steering and regulation of any organization (such as a corporation or business).

Government Programme on Electromobility
The Government Programme on Electromobility, adopted in 2011, bundles the Federal Government's measures in the field of electromobility with the aim of developing Germany into a lead provider and lead market in this area.

Greenhouse gases (GHG)
Greenhouse gases (GHG) are gases that influence the temperature of the Earth's surface in the Earth's atmosphere through the greenhouse effect.

Greenwashing
Greenwashing is the attempt to establish an unjustified 'green image'. It suggests sustainability or environmental friendliness, although this is only partially justified or not justified at all.

Gross domestic product
Gross domestic product (GDP) is the value of all goods and services produced by an economy within one year. GDP is an indicator of the economic performance of an economy in international comparison.

Hardcore restrictions
Hardcore restrictions are agreements that violate antitrust law, e.g. price or quantity agreements or agreements on the sharing of markets.

High-Tech Strategy (HTS)
The High-Tech Strategy (HTS) has been the Federal Government's policy approach to integrating innovation funding across all federal ministries in the past four legislative periods. A strategy paper was presented in each of these legislative periods. The High-Tech Strategy 2025 was the strategy paper of the last legislative period and was adopted by the Federal Cabinet in September 2018.

High-value technology
High-value technology goods are those R&D-intensive goods (cf. there) for whose production more than 3 percent but not more than 9 percent of turnover is spent on research and development on an annual average.

Incremental innovation
An innovation by improving an existing product is called incremental. In contrast, radical innovation (cf. there) refers to fundamental innovations that lead to completely new product concepts and technical solutions.

Infant industries
Infant industries are young industries or new economic sectors within an economy. In their early stages of development, they are usually not yet in a position to compete with already established competitors in other economies.

Innovation expenditure
Innovation expenditure includes all R&D expenditure (internal plus external) as well as other internal and external expenditure required to implement innovation projects. This includes, for example, conceptual work, production preparation, market research and marketing concepts, further training as well as the acquisition of tangible assets for innovations.

Innovation intensity
The innovation intensity describes companies' innovation expenditure relative to turnover in a corresponding year.

Interoperability
Interoperability is the ability of a system to interact with other systems without access restrictions or other barriers and to exchange information in a meaningful way.

Joint Task 'Improvement of the Regional Economic Structure' (GRW)
The central instrument of regional policy in Germany is the Federal Government-Länder Joint Task 'Improvement of the Regional Economic Structure' (Gemeinschaftsaufgabe 'Verbesserung der regionalen Wirtschaftsstruktur', GRW). Since 1969, the Federal Government has shared responsibility for balanced regional development in Germany through the GRW. The cooperation between the Federal Government and the Länder in the GRW is constitutionally regulated in Article 91a of the Basic Law and specified in the GRW Act.

Knowledge economy
The knowledge economy comprises the R&D-intensive industries (cf. there) and the knowledge-intensive services (cf. there).

Knowledge-intensive services
Knowledge-intensive services are characterized by the fact that the proportion of employees with a university degree is above average.

Lock-in effect
A lock-in effect (derived from the English term 'to lock in') occurs when the costs of a possible system change, for example from one platform to another, exceed the expected additional benefits.

Manufacturing sector
Manufacturing is by far the largest part of the industrial sector, which includes all industries except energy and construction. Characteristic industries are, for example, the food industry, mechanical engineering, the manufacture of motor vehicles/vehicle parts, the manufacture of metal products and the chemical industry.

Motorized private transport (MPT)
Motorized private transport (MPT) refers to the movement of persons using a motorized means of transport at their own disposal. The use of passenger cars both as a driver and as a passenger falls under MPT.

Multi-cloud
A multi-cloud describes the use of multiple cloud computing services in a single heterogeneous architecture. The cloud solutions are distributed across multiple cloud providers and cloud environments. A typical multi-cloud architecture aims to avoid dependency on a single cloud provider.

Multihoming
Multihoming is the ability for actors to use different platforms at the same time.

National Hydrogen Strategy
The National Hydrogen Strategy adopted in June 2020 serves as a framework for action for the future production, transport, use and re-utilization of hydrogen. It also defines steps that are necessary to contribute to achieving the climate goals and to create new value chains for the German economy.

Negative emissions
Negative emissions result from the removal of greenhouse gases directly from the atmosphere. The concepts here range from natural approaches such as reforestation to purely technical processes, such as the combination of direct air capture technologies (cf. there) with subsequent storage of the captured CO_2.

Network effects
Network effects occur when the individual benefit of an activity or a product depends on the number of actors who also engage in this activity or consume this product. A distinction is made between direct and indirect as well as positive and negative network effects.

New Mission Orientation
New Mission Orientation is an approach to R&I policy that focuses on addressing grand societal challenges and aims at transformative change in the economy and society. To this end, so-called missions are formulated that specify concrete transformation goals and are to be implemented through R&I projects as well as political measures and frameworks.

(Non-substitutable) complementarity
Complementarity describes, from an economic perspective, the idea that two things complement each other and together create more value than the sum of the values when the two are used individually. Non-substitutable complementarity means that the things that complement each other to create a higher added value cannot be replaced by alternatives.

One-stop shop
In public administration as well as in business, a one-stop shop is the possibility of carrying out all the administrative steps necessary to achieve an objective in a single place.

Oslo Manual
The OECD's Oslo Manual contains guidelines for the statistical recording of innovation activities. This manual goes beyond the R&D concept of the Frascati Manual (cf. there) and differentiates between different forms of innovation. The Oslo Manual is the basis of the Community Innovation Surveys, which have been conducted four times in Europe so far. The most recent revision of the Oslo Manual dates from 2018.

Patent Cooperation Treaty (PCT)
In 1970, the procedure for filing international patent claims was simplified with the conclusion of the Patent Cooperation Treaty (PCT) under the authority of the World Intellectual Property Organization (WIPO), which was founded in 1969. Inventors from PCT states can file a preliminary application with WIPO and file a patent application in the individual contracting states within one year, whereby the date of filing with WIPO is taken as the priority date.

Portfolio
In general, a portfolio is a collection of things within a category.

Pre-market and market area
Compared to the market area, the pre-market area describes the early phases of an innovation in which the development has not yet progressed so far that it has already been introduced to the market. Accordingly, the market area describes the development phases of an innovation that are already more advanced.

Programme family 'Innovation and Structural Change'
With the programmes in the 'Innovation and Structural Change' programme family, the BMBF supports the promotion of regional innovation potential in structurally weak regions. The programme family is an element of the nationwide German funding system for structurally weak regions.

Public health
Public health is defined as the science and practice of preventing disease, prolonging life and promoting health through organized efforts of society. It includes, among others, the fields of prevention, target group-specific health research and health services research.

R&D intensity
R&D intensity is the share of expenditure on research and development (R&D, cf. there) in the turnover of a company or a sector or in the gross domestic product of a country.

R&D-intensive goods
R&D-intensive goods are composed of cutting-edge technology goods (cf. there) and high-value technology goods (cf. there).

R&D-intensive industry
R&D-intensive industry comprises the cutting-edge technology (cf. there) and high-value technology (cf. there) sectors.

R&D planning system
The Federal Government's R&D planning system (Leistungsplansystematik) assigns the Federal Government's research expenditures to various categories.

Radical innovation
A radical innovation is a fundamental innovation that leads to completely new product concepts, technical solutions or services. In contrast, incremental innovation (cf. there) refers to the improvement of an existing product or process.

Rebound effects
In energy economics, a rebound effect refers to the characteristic that expected energy savings through efficiency increases do not fully materialize. Behavioural adjustments to increases in efficiency lead to the savings being lower than expected.

Research and Development (R&D)
Research and development (R&D) and research and innovation (R&I, cf. there) are not used synonymously. The OECD's so-called Frascati Manual (cf. there) defines R&D as systematic, creative work to increase the stock of knowledge – also with the aim of finding new applications. The term R&D covers the three areas of basic research, applied research and experimental development.

Research and Innovation (R&I)
Research and innovation (R&I) and research and development (R&D, cf. there) are not used synonymously. R&D is only one aspect of R&I activities. Innovation, as defined in the OECD's Oslo Manual, involves the introduction of new or significantly improved products (goods and services) or processes.

Smart specialization
The smart specialization approach was developed within the framework of the European Commission's cohesion policy with the aim of promoting structural change towards knowledge- and innovation-led growth. This location-based approach is about identifying a region's most promising fields of development based on its existing strengths and potentials.

Social innovations
Changes in the use of technologies as well as changes in lifestyles, business and financing models, ways of working and forms of organization are referred to as social innovations and include changes in social practices. Social innovations can be both complementary to and a consequence of a technological innovation, or completely independent of it.

Start-ups
Start-ups are young companies with innovative business ideas and high growth potential.

Start-up rate
The start-up rate is the number of start-ups in relation to the overall number of enterprises.

Sustainable Development Goals (SDGs)
In 2015, the global community adopted the 2030 Agenda, which contains 17 SDGs. These are: End poverty in all its forms everywhere; End hunger, achieve food security and improved nutrition and promote sustainable agriculture; Ensure healthy lives and promote well-being for all at all ages; Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all; Achieve gender equality and empower all women and girls; Ensure availability and sustainable management of water and sanitation for all; Ensure access to affordable, reliable, sustainable and modern energy for all; Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; Reduce inequality within and among countries; Make cities and human settlements inclusive, safe, resilient and sustainable; Ensure sustainable consumption and production patterns; Take urgent action to combat climate change and its impacts; Conserve and sustainably use the oceans, seas and marine resources for sustainable development; Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss; Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels; Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Telemedicine
Telemedicine comprises medical care across spatial and temporal (asynchronous) distances as well as general care concepts for the provision of medical services with the help of information and communication technologies.

Total Cost of Ownership (TCO)
In resource economics, the Total Cost of Ownership (TCO) evaluates the direct resource consumption in

the production, use and disposal of a product over its entire lifetime at market prices. Taxes, duties and subsidies are not included in the calculation, as from an economic perspective they are merely transfers between households, companies and the state.

Transnational patent applications
Transnational patent applications are applications in patent families with at least one application to the World Intellectual Property Organization (WIPO) via the PCT procedure (cf. there) or one application to the European Patent Office (EPO). For the export-oriented German economy, such patents are of particular importance because they involve the protection of the invention beyond the home market.

Value added
Value added is the sum of all factor incomes (wages, salaries, interest, rents, leases, distribution profits) generated in a period in the national accounts and corresponds to the national income (social product). In the operational sense, value added includes the production value per period minus the intermediate inputs received from other enterprises in this period.

Value chain
The value chain describes the manufacturing process of a product based on the activities it goes through from the starting material to its use. The stages in the process include, for example, internal logistics, production, external logistics, marketing and sales, and service. The stages can be organized based on the division of labour and can be carried out by different companies.

Venture capital
Venture or risk capital is the seed capital for start-ups and young companies. This also includes funds that are used to support the equity base of small and medium-sized enterprises so they can expand and implement innovative, sometimes high-risk projects. For investors, the investment of venture capital is also high-risk, hence the term risk capital. Equity capital in the form of venture capital is often provided by special venture capital companies (capital investment companies). A distinction is made between the seed, start-up and later stages.

Winner-takes-all effect
The winner-takes-all effect describes a market development in which only one supplier remains on the market in the end. Network effects and economies of scale (cf. there) can cause this development.

'Zukunftsvertrag Studium und Lehre stärken'
The 'Zukunftsvertrag Studium und Lehre stärken' (Pact for Future Strengthening Study and Teaching) is a Federal Government-Länder agreement that aims to achieve a high quality of studying and teaching across the board, good study conditions across the German higher education landscape and the maintenance of study capacities in line with demand.

D 4 Economic Sectors in R&D-intensive Industries and Knowledge-intensive Commercial Services[483]

R&D-intensive industries within the Classification of Economic Activities, 2008 edition (WZ 2008) (4-digit classes) n.e.c. = not elsewhere classified

Cutting-edge technology

20.20 Manufacture of pesticides and other agrochemical products
21.10 Manufacture of basic pharmaceutical products
21.20 Manufacture of pharmaceutical preparations
25.40 Manufacture of weapons and ammunition
26.11 Manufacture of electronic components
26.20 Manufacture of computers and peripheral equipment
26.30 Manufacture of communication equipment
26.51 Manufacture of instruments and appliances for measuring, testing and navigation similar instruments and appliances
26.60 Manufacture of irradiation, electromedical and electrotherapeutic equipment
26.70 Manufacture of optical and photographic equipment
29.31 Manufacture of electrical and electronic equipment for motor vehicles
30.30 Manufacture of air- and spacecraft and related machinery
30.40 Manufacture of military fighting vehicles

High-value technology

20.13 Manufacture of other inorganic basic materials and chemicals
20.14 Manufacture of other organic basic materials and chemicals
20.52 Manufacture of glues
20.53 Manufacture of essential oils
20.59 Manufacture of other chemical products n.e.c.
22.11 Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
22.19 Manufacture of other rubber products
23.19 Manufacture and processing of other glass, including technical glassware
26.12 Production of loaded electronic boards
26.40 Manufacture of consumer electronics
27.11 Manufacture of electric motors, generators and transformers
27.20 Manufacture of batteries and accumulators
27.40 Manufacture of electric lighting equipment
27.51 Manufacture of electric domestic appliances
27.90 Manufacture of other electrical equipment n.e.c.
28.11 Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
28.12 Manufacture of fluid power equipment components and systems
28.13 Manufacture of other pumps and compressors classified
28.15 Manufacture of bearings, gears, gearing and driving elements
28.23 Manufacture of office machinery and equipment (excluding computers and peripheral equipment)
28.24 Manufacture of power-driven hand tools
28.29 Manufacture of other general-purpose machinery n.e.c.
28.30 Manufacture of agricultural and forestry machinery
28.41 Manufacture of metal forming machinery
28.49 Manufacture of other machine tools
28.93 Manufacture of machinery for food, beverage and tobacco processing
28.94 Manufacture of machinery for textile, apparel and leather production
28.95 Manufacture of machinery for paper and paperboard production
28.99 Manufacture of other special-purpose machinery n.e.c.
29.10 Manufacture of motor vehicles
29.32 Manufacture of other parts and accessories for motor vehicles
30.20 Manufacture of railway locomotives and rolling stock
32.50 Manufacture of medical and dental instruments and supplies

Knowledge-intensive commercial services within the Classification of Economic Activities, 2008 edition (WZ 2008) (3-digit classes)

Knowledge-intensive services

Emphasis on finance and assets

411 Development of building projects
641 Monetary intermediation
642 Activities of holding companies
643 Trusts, funds and similar financial entities
649 Other financial service activities, except insurance and pension funding
651 Insurance
652 Reinsurance
653 Pension funding
661 Activities auxiliary to financial services, except insurance and pension funding
663 Fund management activities
681 Buying and selling of own real estate
683 Real estate activities on a fee or contract basis
774 Leasing of intellectual property and similar products, except copyrighted works

Emphasis on communication

611 Wired telecommunications activities

612 Wireless telecommunications activities
613 Satellite telecommunications activities
619 Other telecommunications activities
620 Computer programming, consultancy and related activities
631 Data processing, hosting and related activities, web portals
639 Other information service activities n.e.c.

Emphasis on technical consulting and research
711 Architectural and engineering activities and related technical consultancy
712 Technical testing and analysis
721 Research and experimental development on natural sciences and engineering
749 Other professional, scientific and technical activities n.e.c.

Emphasis on non-technical consulting and research
691 Legal activities
692 Accounting, bookkeeping and auditing activities; tax consultancy
701 Activities of head offices
702 Management consultancy activities
722 Research and experimental development on social sciences and humanities
731 Advertising
732 Market research and public opinion polling
821 Office administrative and support activities

Emphasis on media and culture
581 Publishing books and periodicals; other publishing activities
582 Software publishing
591 Motion picture, video and television programme activities
592 Sound recording and music publishing activities
601 Radio broadcasting
602 Television programming and broadcasting activities
741 Specialized design activities
743 Translation and interpreting activities
823 Organization of conventions and trade shows
900 Creative, arts and entertainment activities
910 Libraries, archives, museums and other cultural activities

Emphasis on health
750 Veterinary activities
861 Hospital activities
862 Medical and dental practice activities
869 Other human health activities n.e.c.

D 5 Recent Studies on the German Innovation System

The Commission of Experts for Research and Innovation (EFI) regularly commissions studies on topics that are relevant to innovation policy. These studies can be accessed via the EFI website (www.e-fi.de/en/publications/studies) in the series 'Studies on the German innovation system' (Studien zum deutschen Innovationssystem). The findings are integrated into the Report of the Commission of Experts.

1-2022
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2-2022
Kladroba, A.; Belitz, H.; Lehmann T. (2022): Forschung und Entwicklung in Staat und Wirtschaft. Deutschland im internationalen Vergleich. Studien zum deutschen Innovationssystem. Berlin: EFI.

3-2022
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4-2022
Neuhäusler, P.; Rothengatter, O. (2022): Patent Applications – Structures, Trends and Recent Developments 2021. Studien zum deutschen Innovationssystem. Berlin: EFI.

5-2022
Stephen, D.; Stahlschmidt, S. (2022): Performance and Structures of the German Science System 2022. Studien zum deutschen Innovationssystem. Berlin: EFI.

6-2022
Schiersch, A.; Ingwersen, K.; Gulden, V.-S. (2022): FuE-intensive Industrien und wissensintensive Dienstleistungen im internationalen Vergleich. Studien zum deutschen Innovationssystem. Berlin: EFI.

7-2022
Kroll, H.; Berghäuser, H.; Blind, K.; Neuhäusler, P.; Scheifele, F.; Thielmann, A.; Wydra, S. (2022): Schlüsseltechnologien. Studien zum deutschen Innovationssystem. Berlin: EFI.

8-2022
Sievers, L.; Grimm, A. (2022): Innovationstätigkeit des Automobilsektors – Analyse mit Fokus auf nachhaltigen Antriebstechnologien und Digitalisierung. Studien zum deutschen Innovationssystem. Berlin: EFI.

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11-2022
Büchel, J.; Demary, V.; Engels, B.; Graef, I.; Koppel, O.; Rusche, C. (2022): Innovationen in der Plattformökonomie. Eine ökonomische und rechtliche Analyse. Studien zum deutschen Innovationssystem. Berlin: EFI.

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Bratan, T.; Schneider, D.; Heyen, N.; Pullmann, L.; Friedewald, M.; Kuhlmann, D.; Brkic, N.; Hüsing, B. (2022): E-Health in Deutschland – Entwicklungsperspektiven und internationaler Vergleich. Studien zum deutschen Innovationssystem. Berlin: EFI.

13-2022

Neuhäusler, P.; Rammer, C.; Frietsch, R.; Feidenheimer, A.; Stenke, G.; Kladroba, A. (2022): Neue Liste FuE-intensiver Güter und Wirtschaftszweige sowie wissensintensiver Wirtschaftszweige 2021. Studien zum deutschen Innovationssystem. Berlin: EFI.

14-2022

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D 7 Endnotes

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1 Cf. here and below SPD et al. (2021).
2 Cf. EFI (2021: chapter A 3).
3 In the past four legislative periods, the so-called High-Tech Strategy (HTS) was the Federal Government's policy approach to integrating innovation funding across all federal ministries. The HTS 2025 was the strategy paper of the last legislative period. Cf. Bundesregierung (2018). The accompanying research of the HTS 2025 was carried out by the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI). Cf. https://www.isi.fraunhofer.de/de/competence-center/politik-gesellschaft/projekte/htf2025.html (last accessed on 14 January 2022).
4 Cf. EFI (2021: chapter B 1).
5 In 2019, around 59 percent of companies in Germany conducted innovation activities. Around 20 percent of companies were innovation-active and engaged in R&D and around 39 percent of companies engaged in innovation activities without conducting R&D. Cf. ZEW (2021: 3).
6 Cf. SPD et al. (2021: 19).
7 Cf. here and below https://www.stifterverband.org/pressemitteilungen/2021_11_12_forschung_und_entwicklung (last accessed on 14 January 2022).
8 Cf. Rammer et al. (2022).
9 The budgeted figures for 2021 and 2022 are subject to particularly high uncertainties, as many companies did not provide any specific budget figures in the survey.
10 During the past two years, there has been immense new borrowing – in 2020, net borrowing was €130.5 billion and in 2021, €240.2 billion. Cf. BMF (2021b: 37) and https://www.bundeshaushalt.de/fileadmin/de.bundeshaushalt/content_de/dokumente/2021/soll/Nachtrags-HG%202021%20gesamt.pdf (last accessed on 14 January 2022). Net borrowing of €99.7 billion is planned for the current year. Cf. https://www.bundesfinanzministerium.de/Content/DE/Pressemitteilungen/Finanzpolitik/2021/06/2021-06-23-regierungsentwurf-bundeshaushalt-2022.html (last accessed on 14 January 2022). The coalition parties have announced that they will comply with the requirements of the debt brake from 2023. Cf. SPD et al. (2021: 158).
11 Cf. SPD et al. (2021: 59); SPD et al. (2021: 158 f.).
12 Cf. Heinemann et al. (2021).

A 1

13 Status as of January 2022.
14 Cf. SPD et al. (2021: 62).
15 To create purchase incentives for electric vehicles without a purchase premium, a CO_2 price of more than €200 per tonne would currently be necessary.
16 The exception is air transport, which is subject to the EU ETS. Cf. on the Fuel Emissions Trading Act http://www.gesetze-im-internet.de/behg/BJNR272800019.html (last accessed on 14 January 2022) and EFI (2020: 20 f.).
17 Cf. SPD et al. (2021: 62 f.).
18 Cf. SPD et al. (2021: 62 f.).
19 Cf. o.V. (2021b).
20 Cf. SPD et al. (2021: 164).
21 This is shown by the discussion on the classifications of gas-fired power plants as sustainable technologies at EU level.
22 According to the coalition agreement, the reform of state-induced price components in the energy sector will aim at systematic, consistent, transparent and, as far as possible, distortion-free competitive conditions, enable sector coupling and thus create a level playing field for all energy sources and sectors. Moreover, according to the coalition agreement, the CO_2 price will play a key role in this. By reducing superfluous, ineffective and environmentally and climate damaging subsidies and expenditures in the budget, the governing parties want to gain additional budgetary leeway. Cf. SPD et al. (2021: 62 and 162).
23 Regarding the harmfulness of subsidies to the climate, the Federal Government's 28th Subsidy Report states: 'A quantified estimate of the greenhouse gas reduction effect is useful for a targeted review of the climate policy impact of subsidies. The external commissioning of an evaluation study could help to quantify the greenhouse gas reduction potentials of

subsidies more precisely in the context of subsidy reporting.' BMF (2021a: 6), own translation.

24 Cf. https://www.bmuv.de/download/eckpunkte-pilotprogramm-fuer-klimaschutzvertraege (last accessed on 14 January 2022).

25 The BMUV refers to this as 'climate protection contracts'.

26 In its Annual Report 2019, the Commission of Experts stated that the diffusion of technologies and business models that are important for the energy transition is inhibited by CO_2 prices that are too low. Cf. EFI (2019: chapter B 2).

27 Cf. Helm et al. (2003) and Richstein (2017).

28 A CCfD is a contract-based instrument and is based on a mutual payment obligation of the contracting parties, which results from the difference between a contractually fixed price, the strike price, and the market price for CO_2 emissions. Companies thus have an incentive to base their investments or the costs of reducing emissions on this strike price. Cf. Helm et al. (2003) and Richstein (2017). The BMUV's draft guideline on CCfD provides for a bidding process in which companies submit bids for strike prices and the lowest bids are awarded the contract. Competition on this strike price leads to the efficient use of certain technologies under given conditions.

29 Cf. Gerres and Linares (2020).

30 Cf. IPCC (2021) and Rickels and Schwinger (2021).

31 Cf. SPD et al. (2021: 65).

32 Cf. Rickels et al. (2021).

33 Cf. here also BMWi (2021a).

34 Cf. SPD et al. (2021: 26 and 63).

A 2

35 Cf. EFI (2021: chapter A 3).

36 Cf. SPD et al. (2021: 18).

37 Cf. SPD et al. (2021: 28).

38 Cf. https://www.bundesregierung.de/breg-de/suche/fortschreibung-ki-strategie-1824340 (last accessed on 14 January 2022).

39 Cf. Deutscher Bundestag (2021b).

40 o.V. (2021a).

41 EFI (2021: 28 f.).

42 Cf. BMBF (2018).

43 Cf. https://www.bmbf.de/bmbf/shareddocs/pressemitteilungen/de/karliczek-mit-grossen-schritte-uantencomputer-made-in-germany.html and https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210511-BMWi-foerdert-Quantentechnologien-mit-878-Millionen-Euro.html (each last accessed on 14 January 2022) and Deutscher Bundestag (2021c).

44 Cf. VDI Technologiezentrum GmbH (2021).

45 Cf. https://www.tagesschau.de/wirtschaft/technologie/quantencomputer-technologiestandort-deutschland-101.html (last accessed on 14 January 2022).

46 Cf. SPD et al. (2021).

47 Cf. BMVI (2021: 6).

48 Cf. BMVI (2021: 7). A comparison with European countries can be made using the Digital Economy and Society Index (DESI) published by the European Commission. As of the end of 2020, Germany lags behind the EU average (59 percent) in the expansion of broadband networks to enable transmission rates of at least 1 Gbit/s, at 56 percent. In terms of the 5G mobile communications standard, Germany is above the EU average (14 percent) with a network coverage of 18 percent. Cf. Europäische Kommission (2021c). It should be noted that while 4G (LTE) and 5G are currently used in parallel in Germany by means of Dynamic Spectrum Sharing (DSS) based on the existing 4G infrastructure, a separate 5G network (5G Standalone) has also been introduced since 2021, which enables gigabit speeds and also short latencies. Cf. Europäische Kommission (2021c).

49 The Digitalization Index 2021 was determined by the Cologne Institute for Economic Research on behalf of the BMWi and comprises 37 indicators that measure both the internal and external effects of digitalization on companies. Cf. Büchel et al. (2020) and Büchel and Engels (2021).

50 Cf. SPD et al. (2021: 16).

51 Cf. https://www.onlinezugangsgesetz.de/Webs/OZG/DE/grundlagen/info-ozg/info-leistungen/info-leistungen-node.html (last accessed on 14 January 2022).

52 In addition to the 84 services available online under the OZG, a total of 34 services were made available online in at least one pilot municipality each during the period 1 January 2021 to 30 September 2021. Cf. Deutscher Bundestag (2021d).

53 Cf. NKR (2021: 19).

54 Cf. also EFI (2021: chapter A 3).

55 Cf. SPD et al. (2021: 15).

56 As of mid-2021, 36 Federal Government institutions are connected to the Federal Cloud. Cf. https://www.move-online.de/meldung_36295_Angebot+w%C3%A4chst.html (last accessed on 14 January 2022). The Federal Cloud Box, which employees of the Federal Government can use to store, edit and exchange data across authorities and

departments, is based on an open source solution from the company Nextcloud. Cf. https://www.itzbund.de/DE/itloesungen/standardloesungen/bundescloudbox/bundescloudbox_node.html;jsessionid=D91CDAE04EA0039572BEAEA2CD84F362.internet961 (last accessed on 14 January 2022). Extensions and consolidations of services based on Microsoft are currently being planned. Cf. https://www.heise.de/news/Microsoft-soll-die-Bundescloud-erweitern-helfen-6012818.html (last accessed on 14 January 2022). The consolidated multi-cloud solution would thus include open source and Microsoft solutions.

57 Cf. SPD et al. (2021: 15).

58 Cf. https://www.heise.de/news/Microsoft-soll-die-Bundescloud-erweitern-helfen-6012818.html (last accessed on 14 January 2022).

59 According to the BSI, the threat situation has increased from 'tense' to 'tense to critical'. Cf. BSI (2020: 9) and BSI (2019); BSI (2021: 9).

60 https://www.bsi.bund.de/DE/Service-Navi/Presse/Pressemitteilungen/Presse2021/211211_log4Shell_WarnstufeRot.html (last accessed on 14 January 2022).

61 Examples of cyber attacks and security vulnerabilities from the area of administration include the Federal Environment Agency, which had to rebuild its email system after a cyber attack and the Government Site Builder (GSB), the German federal administration's content management solution for websites, which is affected by the critical Log4Shell vulnerability. Cf. https://www.bsi.bund.de/SharedDocs/Cybersicherheitswarnungen/DE/2021/2021-549032-10F2.pdf;jsessionid=EAE6A7F2EAEE6D21630A7606FE9E0067.internet461?__blob=publicationFile&v=10 (last accessed on 14 January 2014). One example from the world of science is the TU Berlin. Cf. https://www.tu.berlin/en/topics/restricted-it-services (last accessed on 14 January 2022). Here, a cyber attack in April 2021 led to restrictions in IT services at the university. In addition, a Bitkom study concludes that 86 percent of German companies have suffered damage from cyber attacks within the last two years. Cf. https://www.bitkom.org/Presse/Presseinformation/Angriffsziel-deutsche-Wirtschaft-mehr-als-220-Milliarden-Euro-Schaden-pro-Jahr (last accessed on 14 January 2022).

62 Cf. SPD et al. (2021: 16 f.).

63 Cf. EFI (2020).

64 Cf. https://www.tagesschau.de/wirtschaft/unternehmen/volkswagen-chipmangel-umsatz-gewinn-auslieferungen-quartalsbericht-101.html and https://www.tagesschau.de/wirtschaft/verbraucher/lieferengpaesse-folgen-verbraucher-101.html (each last accessed on 14 January 2022).

65 Cf. Kleinhans and Baisakova (2020).

66 Cf. SPD et al. (2021: 26 f.).

67 Cf. https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/12/20211220-32-mikroelektronik-projekte-in-den-startlochern.html (last accessed on 14 January 2022).

68 Cf. SPD et al. (2021: 21).

69 Cf. SPD et al. (2021: 83).

70 Cf. SPD et al. (2021: 17).

A 3

71 Cf. Müller (2021). STEM stands for science, technology, engineering and mathematics.

72 Cf. Hoch et al. (2021).

73 Cf. acatech and Körber-Stiftung (2020).

74 IT stands for information technology.

75 According to estimates by Anger et al. (2020), 20,000 additional IT positions will be needed to implement the digitalization strategy at schools. Cf. Anger et al. (2020).

76 Digital education is currently only integrated into the teacher training programme in a few Länder. Cf. Autorengruppe Bildungsberichterstattung (2020). The opportunities for teachers to participate in advanced and continuing education programmes for teaching and learning with digital technologies differ significantly between the Länder. Cf. Mußmann et al. (2021).

77 Cf. SPD et al. (2021: 94).

78 Cf. SPD et al. (2021: 96).

79 Cf. SPD et al. (2021: 95 f.).

80 Cf. SPD et al. (2021: 22).

81 Cf. SPD et al. (2021: 22).

82 Cf. EFI (2019: chapter B 4).

83 According to a representative survey by the Bertelsmann Foundation, 70 percent of 14- to 20-year-olds felt that their chances of finding an apprenticeship placement had worsened compared to the time before COVID-19. Only 24 percent perceived a deterioration in the chances of getting a university place. More than half of the respondents complained about orientation difficulties in the information system for career choice. Cf. Barlovic et al. (2021).

84 Cf. EFI (2021).

85 Cf. SPD et al. (2021: 66 f.).

86 The Qualification Opportunities Act (Qualifizierungschancengesetz) came into force on 1 January 2019. Its funding provisions were further

expanded on 1 October 2020 by the Act on the Promotion of CET in Structural Change and the Further Development of Training Assistance, short Work of Tomorrow Act (Gesetz zur Förderung der beruflichen Weiterbildung im Strukturwandel und zur Weiterentwicklung der Ausbildungsförderung (Arbeit-von-morgen-Gesetz)).

87 Cf. Klaus et al. (2020).

88 Cf. SPD et al. (2021: 68).

89 Cf. EFI (2021: chapter B 2).

90 Cf. EFI (2021: 67).

91 Cf. EFI (2021).

92 BAföG is the abbreviation for Bundesausbildungsförderungsgesetz (Federal Training Assistance Act).

93 Cf. SPD et al. (2021: 67).

94 Cf. SPD et al. (2021: 97).

A 4

95 Cf. here and below EFI (2019: chapter B 1).

96 Cf. SPD et al. (2021: 30 f. and 169).

97 Cf. SPD et al. (2021: 19 and 30 f.).

98 Cf. SPD et al. (2021: 169). So far, the Future Fund includes the ERP/Future Fund Growth Facility, the GFF/EIF Growth Facility, the DeepTech Future Fund and the Growth Fund, which was already launched in the new legislative period in December 2021 and is aimed at institutional investors. Cf. https://www.bmwi.de/Redaktion/DE/Artikel/Wirtschaft/zukunftsfonds.html, https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Internationales_Finanzmarkt/zukunftsfonds.html, https://kfw-capital.de/en/investmentfokus/, https://deeptech-future-fonds.de/ (each last accessed on 14 January 2022) and verbal information from the BMWi dated 20 December 2021.

99 Cf. EFI (2019: chapter B 1).

100 The German Sustainable Finance Strategy mentions 'Considering Sustainability in the Future Fund' as one measure. Cf. Bundesregierung (2021a: 30 f.). It is stated here that the Future Fund shares ESG standards in its investments. KfW Capital, which coordinates the Future Fund for the Federal Government and implements the ERP/Future Fund Growth Facility and the Growth Fund as a component of the Future Fund with the support of the ERP Special Fund, sees itself as a responsible VC fund investor. Cf. https://kfw-capital.de/nachhaltigkeit-und-wirkungsmanagement (last accessed on 14 January 2022). The development of an impact investing module proposed here goes beyond this.

101 Cf. SPD et al. (2021: 19).

102 Cf. SPD et al. (2021: 19 and 169).

103 Cf. SPD et al. (2021: 21).

104 In particular, the results of the cross-sectional evaluation 'Support Landscape for Innovative Start-ups' (Unterstützungslandschaft für innovative Gründungen) should also be considered, which aims to analyze the overall range of relevant support measures. Cf. https://www.zew.de/forschung/projekte/querschnittsevaluation-unterstuetzungslandschaft-fuer-innovative-gruendungen (last accessed on 14 January 2022).

105 Cf. SPD et al. (2021: 21).

106 Cf. here and below SPD et al. (2021: 128).

107 Cf. here also EFI (2020: chapter B 1).

108 Cf. https://www.innovation-strukturwandel.de/strukturwandel/de/home/home_node.html (last accessed on 14 January 2022).

109 Cf. SPD et al. (2021: 36).

110 Cf. on smart specialization https://s3platform.jrc.ec.europa.eu (last accessed on 14 January 2022).

111 Cf. SPD et al. (2021: 36).

112 Cf. EFI (2020: chapter B 1).

113 Cf. SPD et al. (2021: 21) and https://enterprisezones.communities.gov.uk/about-enterprise-zones (last accessed on 14 January 2022).

114 Cf. https://www.clusters4future.de (last accessed on 14 January 2022).

115 Cf. SPD et al. (2021: 33).

A 5

116 Cf. EFI (2021: chapter B 1).

117 Cf. Bertschek et al. (2021a) and Bertschek et al. (2021b).

118 Cf. SPD et al. (2021: 9).

119 Cf. Bertschek et al. (2021a).

120 Cf. Bertschek et al. (2021a).

121 Cf. SPD et al. (2021: 21).

122 Cf. here and below SPD et al. (2021: 20 f.).

123 Cf. Bertschek et al. (2021b).

124 Cf. e. g. EFI (2021: chapter A 5 and chapter B 1).

125 Cf. EFI (2021: chapter B 1).

126 Cf. EFI (2021: chapter B 1).

127 The previously mentioned cross-sectional evaluation 'Support Landscape for Innovative Start-ups' is a step in the right direction.

128 Cf. https://www.idc.com/getdoc.jsp?containerId=prUS47482321 (last accessed on 14 January 2022).

129 In the following, the focus is placed on classic 'hard' technologies. However, there are also 'soft' technologies, such as knowledge and understanding of complex systems and ecosystems, which can be regarded as key enabling technologies. These are not dealt with in this chapter, although they play an important role specifically for the social transformation processes addressed.

130 For example, the terms general purpose technologies (GPTs) and key enabling technologies (KETs) are frequently used terminology. 'GPTs are enabling technologies for a pervasive use in many sectors to foster new products and processes.' Helpman (1998: 3). KETs are defined as 'knowledge-intensive and characterized by high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled labour (…). They enable innovation in processes, goods and services and are of systemic importance for the whole economy.' Europäische Kommission (2009a), own translation.

131 The weighting of these criteria may vary, e.g. depending on the stage of development of a technology. For example, the more advanced the development of a technology, the more likely it would be that complementarity with other technologies would already be apparent; however, performance improvement may be slipping out of focus, or future expected performance improvement rates may be lower than for comparatively less advanced potential key enabling technologies.

132 Cf. e.g. Lipsey et al. (2005) and Bekar et al. (2018).

133 Cf. https://www.bmbf.de/bmbf/de/forschung/zukunftstrends/foresight/foresight-als-methode-der-strategischen-vorausschau-im-bmbf/foresight-als-methode-der-strategischen-vorausschau-im-bmbf_node.html (last accessed on 14 January 2022).

134 For an example cf. Fuchs (2021).

135 Cf. VDE (2006) and https://netzpolitik.org/2010/14-thesen-zu-den-grundlagen-einer-gemeinsamen-netzpolitik-der-zukunft/ (last accessed on 14 January 2022).

136 Cf. Edler et al. (2020).

137 Cf. Edler et al. (2020).

138 Technological sovereignty is defined in different ways. The Commission of Experts builds on the Fraunhofer ISI definition because it takes into account both the dimension of mastery of key enabling technologies and the dimension of availability.

139 The element of local learning is based on the one hand on the fact that knowledge is not considered a public good but a latent public good, and on the other hand on the fact that corresponding absorptive capacities must be available to be able to absorb knowledge from others. Cf. Nelson (1989) and Cohen and Levinthal (1989).

140 Cf. Dosi (1988) and Foray (2004).

141 Cf. Fagerberg (1994) and Verspagen (1992).

142 Cf. Cantner (1990) and Cantner and Hanusch (1993).

143 Cf. Redding (1999).

144 Cf. Stiglitz (2015).

145 Cf. Greenwald and Stiglitz (2013) and Lin (2012).

146 Cf. Kroll et al. (2022).

147 For example, the European Commission's Key Enabling Technologies Observatory and Advanced Technologies for Industry Monitoring. Cf. https://ati.ec.europa.eu/ (last accessed on 14 January 2022), Europäische Kommission (2009b), Bundesregierung (2018) and Kroll et al. (2022).

148 The breadth of development activities was measured based on patent data. Patent applicants were matched with the Orbis business database and patents were thus assigned a NACE (Nomenclature statistique des activités économiques dans la Communauté européenne – Statistical Classification of Economic Activities in the European Community) class.

149 The breadth of the technological base was measured based on patent data. The dispersion is calculated based on the distribution of patent applications in the IPC (International Patent Classification) classification. Cf. Kroll et al. (2022). It should be noted that the following presentation is not about the application of the technologies, i.e. not about in which sectors or products a technology is used.

150 A standardized measure of dispersion (Herfindahl-Hirschman Index), which by definition lies between zero and one, is shown on both axes. In this way, the representation compares the 13 key enabling technologies with each other, i.e. it does not allow any conclusions to be drawn in comparison with other technologies. For example, development activities in microelectronics are the most concentrated (equal to one) compared to the other twelve technologies, i.e. patent applicants come from fewer industries than is the case with the other technologies. However, due to the standardized presentation, it is not necessarily very concentrated in absolute terms (compared to other technologies not shown).

151 The key enabling technologies under consideration also differ in terms of their current share of scientific publications and how quickly the number of publications is increasing. For example, the bio- and life sciences have the highest share with a comparatively slow increase, while big data and artificial intelligence have the fastest increase with a currently lower share. This also reflects the extent to which a key enabling technology is already established or approximates the expected future development and increase in performance.

152 The analyzed data were prepared by Kroll et al. (2022).

153 The Scopus database serves as the basis for the publication analyses. The database includes publications in more than 22,000 international journals as well as a large number of conference contributions, whereby only journal contributions were considered in the analysis. Cf. Kroll et al. (2022).

154 China here includes mainland China.

155 It is noteworthy that until the beginning of the 2000s China hardly made an appearance, but in the period under consideration it was able to increase publications in this field by a factor of 16.

156 The patent data come from the patent statistics of the European Patent Office (EPO PATSTAT database). Patent applications were included in the analysis if they were filed either via the Patent Cooperation Treaty (PCT) of the World Intellectual Property Organization (WIPO) or directly at the European Patent Office (so-called transnational patents). Cf. Kroll et al. (2022).

157 As the EPO PATSTAT database does not yet contain the current years in full, the period is limited to 2018 to be able to carry out meaningful country comparison analyses.

158 The relative trade balance is calculated as follows: Exports/Imports – 1.

159 The groups of goods on which the trade data are based cannot be clearly assigned to the individual key enabling technologies. The results should therefore be interpreted with caution. Cf. Kroll et al. (2022).

160 The groups of goods on which the trade data are based cannot be clearly assigned to the individual key enabling technologies. The results should therefore be interpreted with caution. Cf. Kroll et al. (2022).

161 In principle, import data should be interpreted with a certain degree of caution. Since a product is attributed to the country in which it was last registered or customs cleared, large trading and transshipment centres can distort the country allocation.

162 Cf. Kroll et al. (2022).

163 Cf. Rühlig (2021: 34 ff.) and Hoffer and Sander (2021).

164 Cf. Kroll et al. (2022).

165 Cf. Kroll et al. (2022).

166 Cf. Kroll et al. (2022) and Frietsch et al. (2018: 14 ff.).

167 Cf. EFI (2020: chapter B 3).

168 Cf. https://merics.org/de/merics-briefs/china-staerkt-instrumente-zur-abwehr-westlicher-sanktionen-und-schwarzer-listen (last accessed on 14 January 2022) and https://www.handelsblatt.com/politik/international/handelspolitik-das-china-risiko-deutsche-unternehmen-geraten-immer-staerker-zwischen-geopolitische-fronten/27134454.html (last accessed on 14 January 2022).

169 Cf. Edler et al. (2021: 2) and Edler et al. (2020: 4).

170 Cf. BMBF (2021b).

171 Cf. BMBF (2021a), March and Schieferdecker (2021) and Schieferdecker and March (2020).

172 'The BMBF understands technological sovereignty as the claim and ability to cooperatively (co-)shape key enabling technologies and technology-based innovations. This includes the abilities to formulate requirements for technologies, products and services in accordance with one's own values, to (further) develop and produce key enabling technologies in line with these requirements, and to help determine standards on global markets.' BMBF (2021a), own translation.

173 Cf. BMBF (2021a).

174 Cf. https://www.bmwi.de/Redaktion/DE/Schlaglichter-der-Wirtschaftspolitik/2021/07/04-im-fokus.html (last accessed on 14 January 2022).

175 Cf. BMWi (2019) and Bundesregierung (2020).

176 These include, for example, the AI strategy and the national bioeconomy strategy.

177 Cf. Bundesregierung (2018).

178 Cf. https://www.bundesregierung.de/breg-de/service/gesetzesvorhaben/rahmenprogramm-mikroelektronik-1809842 (last accessed on 14 January 2022) and BMWi (2021b).

179 The KET funding areas were defined by the European Commission in 2009 and further specified in subsequent years. A concrete implementation of the funding of key enabling technologies was implemented in the Horizon 2020 research framework programme. Cf. Kroll et al. (2022), Europäische Kommission (2009b), Europäische Kommission (2012) and https://www.horizont2020.de/einstieg-neuerungen.htm (last accessed on 14 January 2022).

180 Cf. Kroll et al. (2022).

181 So far, 38 such partnerships have been proposed, including on high performance computing (9), key enabling technologies (19), smart networks and services (11), artificial intelligence, data and robotics (12), photonics (13) and discrete manufacturing technologies (15). Cf. Europäische Kommission (2019a).

182 IPCEIs are funding projects of strategic interest that involve at least two Member States but aim to strengthen the competitiveness and added value of the EU as a whole.

183 Cf. https://www.bmwi.de/Redaktion/DE/Artikel/Energie/ipcei-wasserstoff.html (last accessed on 14 January 2022) and https://www.bmwi.de/Redaktion/DE/FAQ/IPCEI/faq-ipcei.html (last accessed on 14 January 2022).

184 To this end, international partnerships are to be diversified, industrial alliances concluded and strategic dependencies monitored, among other things. Cf. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en (last accessed on 14 January 2022).

185 Cf. Europäische Kommission (2021a) and Europäische Kommission (2021e).

186 Cf. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy/depth-reviews-strategic-areas-europes-interests_en (last accessed on 14 January 2022).

187 Cf. Kroll et al. (2022), Europäische Kommission (2021d) and Europäische Kommission (2021f).

188 Cf. Europäische Kommission (2021a) and Kroll et al. (2022).

189 China's approach is characterized by very ambitious goals and long-term plans. A well-known example of this, in addition to the five-year plans and the Belt and Road Initiative, is the strategic plan Made in China 2025, which, among other things, envisages the massive expansion of key enabling technologies. A total of ten key industries are defined: ICT, machine tools and robotics, green energy and electromobility, aerospace technology, shipbuilding and marine technology, biomedicine and medical devices, and machinery for agriculture. Cf. Kroll et al. (2022) and Zenglein and Holzmann (2019).

190 Cf. EFI (2020: chapter B 3), Zenglein and Holzmann (2019) and Kroll et al. (2022).

191 Cf. Rühlig (2021: 64 ff.) and Hoffer and Sander (2021).

192 Cf. Kroll et al. (2022).

193 Cf. Shi-Kupfer and Ohlberg (2019) and Kroll et al. (2022).

194 Cf. Kroll et al. (2022) and Bardt et al. (2019).

195 AI: National AI Initiative; Nanotechnology: National Nanotechnology Initiative; Robotics: National Robotics Initiative; Production technology: Ensuring American Leadership in Advanced Manufacturing, Advanced Manufacturing Initiative, Advanced Manufacturing Partnership. Cf. Kroll et al. (2022).

196 Cf. Coka et al. (2020).

197 Also under the Biden administration, around two-thirds of US imports from China remain subject to high additional tariffs. Cf. Kolev and Matthes (2021). The US has also imposed export and technology transfer restrictions on China by placing numerous Chinese companies on the so-called Entity List. This means that a licence is required for any export, re-export or transfer of technology, goods or software subject to export control if one of the companies named on this Entity List is involved in the transaction. Cf. Kroll et al. (2022) and https://www.federalregister.gov/documents/2020/12/22/2020-28031/addition-of-entities-to-the-entity-list-revision-of-entry-on-the-entity-list-and-removal-of-entities (last accessed on 14 January 2022).

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198 In 2019, MPT had a share of 69 percent of the kilometres travelled per day and person. Cf. Ecke et al. (2020).

199 The study uses the cut-off approach common in life-cycle analyses, according to which the full environmental burdens are taken into account for all primary materials used, while the environmental burdens of secondary materials are not considered. At the end of life, the burdens from waste treatment are accounted for and no credits are given for recovered secondary materials. Cf. Wietschel et al. (2022).

200 Synthetic fuels refer to liquid carbon-containing fuels that are produced by converting a solid or gaseous energy source, such as biomass or electricity and water. Cf. https://www.bmu.de/themen/luft-laerm-mobilitaet/verkehr/kraftstoffe#c20258 (last accessed 14 January 2022).

201 Cf. Fehrenbach (2019).

202 In addition to the full hybrid, a distinction is also made between micro and mild hybrids. In the micro hybrid, a generator supports the engine start processes of the automatic start-stop system. In addition, these vehicles have a brake energy recovery system. In the mild hybrid, electrical energy is primarily used to support starting. These vehicles are

sometimes capable of driving very short distances purely electrically.

203 Cf. https://www.quarks.de/technik/mobilitaet/so-unterschiedlich-koennen-hybrid-autos-sein (last accessed on 14 January 2022).

204 Cf. https://www.adac.de/verkehr/tanken-kraftstoff-antrieb/alternative-antriebe/hybridantrieb/ (last accessed on 14 January 2022).

205 Cf. https://www.adac.de/verkehr/tanken-kraftstoff-antrieb/alternative-antriebe/wasserstoffauto-so-funktioniert-es (last accessed on 14 January 2022).

206 The study's assumptions imply that improvements in the battery manufacturing process in particular are offset by increased charging capacities. The reduction in greenhouse gas emissions is therefore only due to the change in the energy mix in favour of renewables.

207 Cf. Krail et al. (2021).

208 As long as renewable electricity is not used exclusively in alternative fuels and drive systems.

209 Cf. UBA (2013).

210 In a sensitivity analysis, the study also calculates the emissions over the lifetime of a BEV, taking into account a replacement battery. Here, too, the total emissions still decrease by 39 percent.

211 Plötz et al. (2021) show that with actual driving behaviour, the GHG are two to four times higher than the theoretical values with optimal use.

212 These results can be found in similar form in earlier studies such as Bieker (2021) and Agora Verkehrswende (2019). Buchal et al. (2019) highlight the assumed electricity mix as a key variable for the advantageousness of BEVs. VDI (2020) discuss the location of battery production on the relative advantageousness of BEVs and show that Chinese battery production can have a negative impact.

213 Cf. https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland/stickstoffoxid-emissionen#entwicklung-seit-1990 (last accessed on 14 January 2022).

214 Cf. https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland/emission-von-feinstaub-der-partikelgroesse-pm25#emissionsentwicklung and https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland/emission-von-feinstaub-der-partikelgroesse-pm10#emissionsentwicklung (each last accessed on 14 January 2022).

215 This is due, among other things, to the higher NO_X and especially particulate matter emissions during the production of batteries and fuel cells. Electricity generation also has a relevant influence on total NO_X and particulate matter emissions. Conventional passenger cars with synthetic fuels therefore fare worst with the current electricity mix and the one assumed for 2030, as fuel production requires large amounts of electricity.

216 Data from the Federal Environment Agency show that the concentrations of NO_X, PM_{10} and $PM_{2.5}$ are significantly higher in traffic-related and urban regions than in rural areas. Cf. https://www.umweltbundesamt.de/daten/luft/feinstaub-belastung#feinstaubkonzentrationen-in-deutschland (last accessed on 14 January 2022).

217 Cf. Göbel (2012), https://www.elektroniknet.de/power/energiespeicher/beginn-des-post-lithium-zeitalters.189315.html and https://www.dw.com/de/natrium-statt-lithium-die-akkus-der-zukunft/a-54512116 (each last accessed on 14 January 2022).

218 U.S. Geological Survey (2021) estimates global platinum reserves at 100 thousand tonnes, cobalt reserves at 25 million tonnes and lithium reserves at 86 million tonnes. The study determines a demand for platinum of 49 grams per vehicle for FCEVs and a demand for lithium and cobalt of 6.1 and 9.7 kilograms per vehicle for BEVs. In 2015, the number of passenger cars worldwide was already close to one billion, with an upward trend. If we take this number and the current technology and assume a change of drive system to FCEVs, this will reduce the platinum reserves available worldwide by 49 percent. Replacing all passenger cars with BEVs would reduce onshore cobalt reserves by 39 percent and lithium reserves by 7 percent.

219 Cf. https://www.dw.com/de/natrium-statt-lithium-die-akkus-der-zukunft/a-54512116 (last accessed on 14 January 2022) and https://www.elektroniknet.de/power/energiespeicher/beginn-des-post-lithium-zeitalters.189315.html (last accessed on 14 January 2022).

220 Cf. Vekic (2020) and https://www.princeton.edu/news/2019/06/17/hydrogen-fuel-cells-mundane-materials-might-be-almost-good-pricey-platinum (last accessed on 14 January 2022).

221 In addition to nickel-manganese-cobalt (NMC) batteries, lithium-iron-phosphate (LFP) and lithium-nickel-manganese-oxide (LNMO) batteries, which do not require cobalt, could also be used.

222 Taxes, duties and subsidies are not included in the calculation, as from an economic perspective they are merely transfers between households, companies and the state.

223 This does not change even if the analysis for 2020 assumes a share of 100 percent electricity from re-

newables. Under this assumption, the TCO for BEVs increases slightly due to the associated higher energy costs. For FCEVs and especially for synthetic fuel vehicles, the higher energy costs have an even less favourable impact on the TCO due to the lower efficiency of the entire conversion chain.

224 For PHEVs, the high abatement costs are based on the assumption that 100 percent synthetic electricity-based fuels are used for trips with the combustion engine.

225 Petrakis et al. (1997) show that purely in-house cost degressions through learning by doing do not constitute a market failure and thus do not justify subsidies. Fischer and Newell (2008) and Reichenbach and Requate (2012), however, show that in the case of learning spillovers, subsidies can be welfare enhancing.

226 Cf. KBA (2021a).

227 A rebound effect occurs when a more fuel-efficient vehicle is used more frequently than a more fuel-intensive one. Frondel and Vance (2018) estimate rebound effects from emission standards in transport of up to 70 percent.

228 VAT has a neutral effect here, as it does not change the cost ratio between vehicles with different drive systems.

229 However, it is important to bear in mind that driving generates other externalities, such as emissions of other pollutants, mainly NO_x and particulate matter, as well as time lost due to congestion externalities and accident risks. Petrol and diesel taxes are therefore still too low compared to the sum of externalities.

230 A higher taxation of fuels to also take into account the external costs of NO_x and particulate matter emissions, for example, is still not the first-best solution, since NO_x emissions in particular depend on driving behaviour. However, measuring and taxing NO_x emissions directly would be too technically complex.

231 Stremersch et al. (2007) also show, using the example of hardware and software, that indirect network effects can be quite asymmetrical. The improvement of hardware as infrastructure promotes new software applications. The reverse is not true.

232 Cf. https://www.bmvi.de/SharedDocs/DE/Artikel/G/Alternative-Kraftstoffe/ladeinfrastruktur.html (last accessed on 14 January 2022).

233 Cf. Monopolkommission (2021b: 6 ff.).

234 Cf. https://h2.live (last accessed on 14 January 2022).

235 Liquid organic hydrogen carrier (LOHC) is a carrier oil with high storage capacity for hydrogen. For a description of the technology, cf. Teichmann et al. (2011) and Modisha et al. (2019).

236 Transnational patent applications include patents filed with the European Patent Office (EPO) and/or as international applications with the World Intellectual Property Organisation (WIPO). Cf. Frietsch and Schmoch (2010). The observation period for patent applications ends in 2017, as the allocation of cooperative patent classifications (CPC), which is relevant for the evaluation, only takes place when the EPO or the United States Patent and Trademark Office (USPTO) enters the national patent application phase and is therefore associated with a delay of approximately 18 months. Thus, no meaningful country comparison of patent activities in the field of alternative drive systems is possible in the more recent years.

237 Cf. Sievers and Grimm (2022).

238 This trend of rising patent applications for alternative drive systems is continuing in 2018 and 2019 for patent applications with effect for Germany, as figures from the German Patent and Trade Mark Office show. Cf. DPMA (2020).

239 The pronounced peak in Japan's patent applications in 2011 may be due to Japan's pioneering role and an associated early peak in patent activity there, as well as a change of course in Toyota's patenting strategy, which in recent years has increasingly targeted the application of Toyota's technologies by other carmakers.

240 The figures given refer to Mainland China excluding Taiwan.

241 The normalized RPSs calculated here measure the normalized quotient of the national share of global patent applications in the field of alternative drive technologies and the national share of global patent applications in the field of all drive technologies. The normalized RPSs are defined as the hyperbolic tangent of the natural logarithm of the quotient described multiplied by 100. Thus, the RPSs considered are normalized to the range of values from – 100 (no patent applications in the field of alternative drive technologies) to + 100 (all patent applications in the field of alternative drive technologies).

242 The latest figures from the Federal Motor Transport Authority (Kraftfahrt-Bundesamt, KBA) on monthly new registrations in 2021 indicate that the trend towards a higher market share of alternative drive systems in Germany will continue. In the period from January to October 2021, vehicles with electric drive systems together accounted for 24 percent of new passenger car registrations. Cf. KBA (2021b).

243 Cf. Deutscher Bundestag (2021a), https://www.bundesregierung.de/breg-de/themen/neue-kraftstoffe-und-antriebe-994216 and https://www.bmvi.de/SharedDocs/DE/Artikel/G/Alternative-Kraftstoffe/foerderung-von-fahrzeugen.html (each last accessed on 14 January 2022).
244 Cf. Henning et al. (2019).
245 Cf. Krail et al. (2019).
246 Cf. Agora Verkehrswende (2020).
247 In energy economics, a rebound effect refers to the characteristic that expected energy savings through efficiency increases do not fully materialize.
248 This period of observation was chosen due to the low number of patent applications before 2005.
249 The trend of increasing patent applications in automated and autonomous driving with effect for Germany continues in 2019, as figures of the DPMA show. Cf. DPMA (2020).
250 There are currently 26 test fields in Germany that are recorded within the scope of a test field monitoring commissioned by the Federal Ministry of Transport and Digital Infrastructure. In these test fields, research in the field of automated and interconnected driving is being tested in over 140 projects from Germany and the EU. The focus here is on test operations of automated vehicles and the further development of the safety of automated vehicle technologies and the corresponding electronics and sensor technology. Some test fields also serve to test the ICT infrastructure for interconnecting automated vehicles and to test mobility concepts with automated vehicles in the context of public transport models. Cf. https://www.testfeldmonitor.de/Testfeldmonitoring/DE/Home/home_node.html (last accessed on 14 January 2022).
251 Cf. Bundesregierung (2015).
252 Cf. BMBF (2021c).
253 Cf. https://www.jdsupra.com/legalnews/germany-takes-the-lead-with-a-new-law-7746782 (last accessed on 14 January 2022) and Koller and Matawa (2020).
254 In some US states such as California and Nevada, legal regulations for the test operation of automated and autonomous vehicles already came into force between 2011 and 2013. In the same period, US patent applications in the field of autonomous driving rose sharply (see figure B 2-12). Cf. Dudenhöffer und Schneider (2015) and https://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx (last accessed on 14 January 2022).
255 So far, there are no registration applications for vehicles that comply with automation level 4 according to the legal requirements. Cf. https://www.automotiveit.eu/technology/autonomes-fahren/welcher-autobauer-hat-beim-autonomen-fahren-die-nase-vorn-124.html (last accessed on 14 January 2022) and NPM (2021).
256 Cf. Ecke et al. (2020) and https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Einkommen-Konsum-Lebensbedingungen/Ausstattung-Gebrauchsgueter/Tabellen/liste-fahrzeuge-d.html (last accessed on 14 January 2022).
257 Cf. e.g. Gsell et al. (2016), Schmitt et al. (2017), Hagen and Rückert-John (2016) and https://www.nzz.ch/wirtschaft/wirtschaftspolitik/sharing-economy-wi-bildlegende-ld.86383 (last accessed on 14 January 2022).
258 Platforms for better utilization of one's own car have existed for a long time, initially in the form of noticeboards. In the meantime, many digital versions of these exist on the web, the advantage of which is a larger number of potential matches. For a comprehensive overview of various multimodal and intermodal Mobility-as-a-Service platforms, which cannot be discussed in detail in this report cf. https://boydcohen.medium.com/the-maas-monetization-matrix-by-iomob-a8cc17be5aa (last accessed on 14 January 2022).
259 Cf. Ecke et al. (2020).
260 ShareNow, for example, is the successor to DriveNow (BMW) and car2go (Daimler), WeShare is a subsidiary of the VW Group, while Ford Carsharing (Ford) cooperates with Flinkster (DB). Start-ups like Miles also offer station-independent services. In contrast, Cambio, stadtmobil and teilAuto offer station-based car sharing. Cf. https://www.manager-magazin.de/unternehmen/autoindustrie/carsharing-anbieter-von-share-now-we-share-bis-stadtmobil-im-vergleich-a-d1e2d2d4-ce0b-4dc3-87c3-58a1aab303f3 (last accessed on 14 January 2022).
261 Cf. Ecke et al. (2020).
262 In addition to the VW subsidiary MOIA, the DB subsidiaries ioki and CleverShuttle support local public transport providers as partners in the expansion of on-demand transport.
263 Cf. Bundesregierung (2021e).
264 The 25th to 75th percentile range ranks between 5 and 38 vehicles per 100,000 inhabitants, 10 percent of the cities considered have 96 or more vehicles per 100,000 inhabitants.
265 For example, Rehau (21), Dietzenbach (17.5) as well as Kiel and Düsseldorf (16 each).
266 Cf. Doll and Krauss (2022).
267 Cf. Doll and Krauss (2022).

268 Cf. Doll and Krauss (2022) for a detailed scenario description and the calculation of further scenarios.
269 Members of the Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen, VDV) reported a share of 40 percent of total expenditure for personnel expenses in 2018. In contrast, fuel costs accounted for only 6 percent of total expenditure. Cf. VDV (2020).
270 Coulombel et al. (2019) demonstrate such rebound effects even for current ride pooling services in Paris.
271 Cf. Anas and Lindsey (2011).
272 This refers to the obligation to return, the spatial and temporal restriction of the service and the bundling rate in urban areas. The bundling rate describes the transport performance as a ratio of passenger kilometres travelled to vehicle kilometres travelled. Cf. Bundesregierung (2021e).
273 Cf. DICE (2021), MOIA GmbH (2021), BITKOM (2020) and VZBV (2021).
274 The Mobilithek is the new national access point for mobility data, which will replace the Mobility Data Marketplace (Mobilitäts Daten Marktplatz) and the mCloud in spring 2022. The amendment to the Passenger Transport Act already stipulates that mobility service providers must make their collected data available to third parties via the Mobilithek. While the Mobilithek is a state data platform, a similar concept is being implemented by private enterprises in the Mobility Data Space. Here, companies can make their mobility data available to third parties. Cf. https://www.bmvi.de/SharedDocs/DE/Artikel/DG/mobilithek.html and https://emmett.io/article/mobilithek-nationaler-zugangspunkt-mobilitaetsdaten (each last accessed on 14 January 2022).
275 Cf. https://www.lto.de/recht/kanzleien-unternehmen/k/novelle-pbefg-mobilitaetsatenverordnung-rechtswidrig-geheimnisse (last accessed on 14 January 2022).

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276 Cf. Lerch et al. (2019).
277 Platforms have gained in importance in the course of digitalization but are not actually a new phenomenon. Platforms have always existed, for example in the form of weekly markets, trade fairs and stock exchanges for securities. Cf. Haucap (2021: 426).
278 Cf. Belleflamme and Peitz (2021: 29).
279 Cf. Haucap (2021: 427) and Rochet and Tirole (2003) on the economics of multi-sided markets.
280 Cf. here and below Hoffmann et al. (2021: 6 f.).
281 Cf. here and below Belleflamme and Peitz (2021).
282 Cf. Evans et al. (2011).
283 For example, Bourreau and de Streel (2019) provide an overview of economies of scope in digital markets.
284 Cf. Chen et al. (2021: 3). Some authors also refer to platform ecosystems as innovation platforms, cf. e.g. Cusumano et al. (2021). This is to be distinguished, not quite clearly, from so-called open innovation platforms, whose explicit goal is to develop innovations through the cooperation of the stakeholders.
285 Cf. here and below Gawer and Cusumano (2008).
286 Cf. here and below Hoffmann et al. (2021) and Cennamo and Santaló (2019).
287 Cf. Jones and Tonetti (2020).
288 Cf. e.g. Agrawal et al. (2018) and Brynjolfsson et al. (2011).
289 Cf. Haucap et al. (2020: 16).
290 Cf. here and below Haucap et al. (2020: 16 ff.) and Falck and Koenen (2020: 14 f.).
291 Cf. here and below Haucap et al. (2020: 16 ff.) and Lerch et al. (2019: 5 f.).
292 Cf. here and below Hoffmann et al. (2021: 9) and Büchel et al. (2022: 31).
293 Cf. here and below etventure GmbH (2020) and Hoffmann et al. (2021: 10).
294 Cf. here and below https://dih.telekom.net (last accessed on 14 January 2022) and Büchel et al. (2022).
295 Cf. here and below https://siemens.mindsphere.io/de (last accessed on 14 January 2022).
296 Cf. here and below https://siemens.mindsphere.io/de (last accessed on 14 January 2022) and Friederici et al. (2020).
297 Cf. here and below Friederici et al. (2020) and Falck and Koenen (2020).
298 Cf. Falck and Koenen (2020: 23).
299 These results are based on a company survey conducted by ZEW in the context of the ZEW Business Survey in the Information Economy. The regular survey includes companies with at least five employees from the sectors information and communication technologies (ICT, consisting of ICT hardware and ICT services), media services and knowledge-intensive services (legal and tax consultancy, auditing, public relations and management consultancy, architectural and engineering offices, technical, physical and chemical investigation, research and development, advertising and market research as well as other freelance, scientific and technical activities). All these sectors together

form the information economy industry. The survey was expanded to include manufacturing enterprises. This includes the sub-sectors of chemicals and pharmaceuticals, mechanical engineering, vehicle construction and other manufacturing. The survey was conducted in September 2021 as part of a combined written and online-based survey. In total, the extrapolated results are based on 730 usable responses from the information economy and 455 responses from the manufacturing sector. To ensure the representativeness of the analyses, the answers of the survey participants were extrapolated by the ZEW to the number of all companies in the sectors under consideration. For more information on the ZEW Business Survey cf. https://www.zew.de/publikationen/zew-gutachten-und-forschungsberichte/forschungsberichte/informationswirtschaft/zew-branchenreport-informationswirtschaft (last accessed on 14 January 2022).

300 Cf. here and below Falck and Koenen (2020: 8 and 29 f.).

301 Cf. here and below Koenen and Heckler (2021: 11).

302 Cf. VDMA and McKinsey & Company, Inc. (2020: 18).

303 Cf. https://www.crowdworx.com/de (last accessed on 14 January 2022).

304 Cf. Sims and Woodard (2020).

305 Cf. here and below Haucap (2021: 434).

306 Cf. e.g. Belleflamme and Peitz (2021: 235) or Rietveld and Schilling (2021).

307 Cf. e.g. Crémer et al. (2019).

308 An example of competition for the market in the information and communication technology sector is IBM's leading position in the mainframe computer market, which has been displaced by Intel's hardware and Microsoft's operating system. Intel's and Microsoft's positions have in turn been weakened by suppliers of tablets and smartphones. Cf. e.g. Büchel et al. (2022: 123 ff.).

309 Cf. Cabral (2021).

310 Cf. Lerch et al. (2019: 42 ff.).

311 Cf. e.g. Jones and Tonetti (2020).

312 Cf. e.g. Martens et al. (2020: 16).

313 Cf. e.g. ERT (2021: 4).

314 Cf. e.g. Crémer et al. (2019: 9) and Martens et al. (2020).

315 Cf. BMWi (2020).

316 Cf. here and below EFI (2021), BMWi (2020) and Bundesregierung (2021b).

317 Cf. here and below https://catena-x.net/de (last accessed on 14 January 2022).

318 Cf. SVR (2021: 345 f.) and Bundesregierung (2021b).

319 Cf., for example, the GAIA-X funding competition. Cf. https://www.bmwi.de/Redaktion/DE/Dossier/Dateninfrastruktur-GAIA-X/gaia-x-foerderwettbewerb.html (last accessed on 14 January 2022).

320 In the meantime, several US-American and Chinese companies have also joined GAIA-X.

321 Data and IT security concerns are also cited by companies in other surveys as one of the key barriers to the use of B2B platforms. Cf. e.g. Lundborg and Gull (2019: 12) and Lerch et al. (2019: 32 ff.). For digital platforms in general, cf. also Nietan et al. (2020).

322 Cf. also Lerch et al. (2019: 34) and Haucap et al. (2020: 25 f.).

323 Cf. here and below Haucap et al. (2020: 68).

324 Cf. Europäische Kommission (2020a: 7), IW Köln Consult GmbH (2019: 57 ff.), Lundborg and Gull (2019: 12) and Haucap et al. (2020: 25).

325 Cf. Hoffmann et al. (2021: 22), Lerch et al. (2019: 30), Lundborg and Gull (2019: 12), SVR (2021: 332 f.) and Haucap et al. (2020: 24 f.).

326 Cf. Bundesanzeiger (2021b).

327 Cf. for an overview e.g. SVR (2021: 349).

328 In Germany, several changes were already made to antitrust law in 2017 to better capture the market power of digital platforms. In particular, the introduction of further criteria for assessing the market position of a company in multi-sided markets and networks is worth mentioning (Section 18 subs. 1 No. 3a of the German Act Against Restraints of Competition (Gesetz gegen Wettbewerbsbeschränkungen, GWB)). However, this did not impose any additional behavioural measures on companies with market power. Cf. Haucap (2021: 438 f.).

329 The following five indicators shall be taken into account (Section 19a subs. 1): 1. its dominant position on one or more markets, 2. its financial strength or access to other resources, 3. its vertical integration and its activities on markets that are otherwise interconnected, 4. its access to competitively relevant data, 5. the importance of its activities for third party access to procurement and sales markets as well as its related influence on the business activities of third parties. The decision shall be limited to five years after it becomes final. Cf. Bundesanzeiger (2021a) and Büchel et al. (2022: 110 f.).

330 Section 19a subs. 2 GWB. Cf. here and below Bundesanzeiger (2021a).

331 Cf. https://www.bundeskartellamt.de/SharedDocs/Meldung/DE/Pressemitteilungen/2022/05_01_2022_Google_19a.html?nn=3591286 (last accessed on 14 January 2022).

332 Section 18 subs. 3b GWB and Section 18 subs. 3 No. 3 GWB. Cf. Bundesanzeiger (2021a) and Büchel et al. (2022: 110).

333 Section 19 subs. 2 No. 4 GWB and Section 20 subs. 1a GWB. Specifically, the GWB Digitalization Act states in Section 20 subs. 1a that dependency can also result from the fact that a company is dependent for its own activities on access to data controlled by another company and that the denial of access to such data for a reasonable fee can constitute an unfair obstruction. Cf. Bundesanzeiger (2021a) and Büchel et al. (2022: 110).

334 The proposed legislation builds on the Platform-to-Business Regulation (P2B Regulation) currently in force in the European Union (EU). Cf. Büchel et al. (2022: 105 f.).

335 The European Commission also presented a proposal for a Digital Services Act (DSA) in 2020. This proposal addresses issues related to dealing with illegal or potentially harmful online content and the protection of users' fundamental rights on the internet. Cf. Büchel et al. (2022: 104).

336 A company is considered a gatekeeper if it meets all three of the following criteria: 1. It must have reached a size that has a significant impact on the internal market; 2. It must control a core platform service that serves as an important gateway to end users for business users; 3. It must have an entrenched and lasting position with regard to its activities or be expected to attain such a position soon. These criteria are deemed to be met if a company reaches certain thresholds or if the European Commission comes to this conclusion within the framework of a market investigation based on a case-related qualitative assessment. For the specific thresholds, cf. Europäische Kommission (2020c).

337 For examples of competition-distorting practices by platform operators, cf. e. g. SVR (2021: 334).

338 For the full list of commitments, cf. Europäische Kommission (2020c).

339 Cf. Europäische Kommission (2020c).

340 The European Commission can also impose penalty payments of up to five percent of the average daily turnover. Cf. Europäische Kommission (2020c).

341 These additional measures may be imposed following a market investigation, must be proportionate to the infringement committed and necessary to achieve compliance with the DMA. Structural measures may only be imposed if there is no equally effective behavioural remedy or if such a remedy would be more burdensome than a structural measure. Cf. Büchel et al. (2022: 108 f.) and Europäische Kommission (2020c).

342 For the European Parliament's amendments to the proposed Digital Markets Act cf. https://www.europarl.europa.eu/doceo/document/TA-9-2021-0499_EN.pdf and http://www.fiw-online.de/de/aktuelles/aktuelles/eu-europaeisches-parlament-nimmt-text-zum-digital-markets-act-dma-im-plenum-an (each last accessed on 14 January 2022). The European Council has already agreed on a draft law in October 2021. However, the compromise proposal of the EU Member States does not differ significantly from the original draft law. For an overview of the Council's amendments to the European Commission's original proposal cf. https://cdn.netzpolitik.org/wp-upload/2021/10/Council-DMA-Third-Compromise-Oct-12-2021.pdf (last accessed on 14 January 2022). The final design of the DMA is to be decided in trilogue negotiations between the European Parliament, the European Council and the European Commission in the first half of 2022.

343 The parliamentary draft raised the threshold for the size criterion from at least €6.5 billion annual turnover in the last three financial years in the European Economic Area to €8 billion and the average market capitalization of a company from €65 billion to €80 billion. At the same time, however, the Parliament has added web browsers, virtual assistants and connected TVs to the list of core platform services. Cf. https://cdn.netzpolitik.org/wp-upload/2021/10/Council-DMA-Third-Compromise-Oct-12-2021.pdf (last accessed on 14 January 2022).

344 Cf. https://www.euractiv.de/section/innovation/news/eu-parlament-beschliesst-verordnung-gegen-internet-riesen/ and https://cdn.netzpolitik.org/wp-upload/2021/10/Council-DMA-Third-Compromise-Oct-12-2021.pdf (each last accessed on 14 January 2022).

345 Cf. here and below Larouche and de Streel (2021: 6).

346 Cf. https://www.gisreportsonline.com/r/digital-markets-act (last accessed on 14 January 2022).

347 Cf. here and below Monopolkommission (2021a: 47 ff.) and de Streel et al. (2021: 33 f.).

348 Cf. Franck and Peitz (2021: 24).

349 Cf. https://www.europarl.europa.eu/doceo/document/TA-9-2021-0499_EN.pdf (last accessed on 14 January 2022).

350 Cf. EFI (2019: 53 f.).

351 Cf. Europäische Kommission (2020c) and Franck and Peitz (2021: 22).

352 For an overview cf. SVR (2021: 345 ff.).

353 The Open Data Directive was transposed into national law in Germany in June 2021 by amending the E-Government Act (E-Government-Gesetz, EGovG) and introducing the Act on the Use of Public Sector Data (Datennutzungsgesetz, DNG). Based on the Open Data Act 2.0, the Federal Government also adopted an Open Data Strategy in 2021, the aim of which is to increase the provision and use of data. Cf. Büchel et al. (2022: 142 f.) and Europäische Kommission (2019b).

354 Cf. Europäische Kommission (2020d). The introduction of data trustee models is also enshrined as a measure in the Federal Government's Data Strategy presented in January 2021 and was included in the new Federal Government's coalition agreement. Cf. Bundesregierung (2021b: 34) and SPD et al. (2021: 17).

355 Another planned measure to increase data availability is to increase the voluntary provision of data by individuals or companies (data altruism). To this end, institutions that collect and process data provided for altruistic purposes should be able to be voluntarily audited and officially registered. Cf. Europäische Kommission (2020d).

356 The specific content of the planned data act is still largely unresolved. A draft regulation is scheduled for the first quarter of 2022. Cf. here and below https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13045-Data-Act-&-amended-rules-on-the-legal-protection-of-databases_en (last accessed on 14 January 2022) and Europäische Kommission (2021b).

357 Cf. Europäische Kommission (2020b). The Federal Government's Data Strategy, presented in January 2021, and the coalition agreement also provide for the establishment of data spaces. To leverage the potential of data, the coalition agreement announces further measures such as the development of data infrastructures, the introduction of a data institute to promote data availability and standardization, and the improvement of access to data for companies. Cf. Bundesregierung (2021b) and SPD et al. (2021).

358 Cf. Europäische Kommission (2011) and Haucap et al. (2020: 71 f.) and specifically on the advantages and obstacles of data sharing Martens et al. (2020) and ERT (2021).

359 Hardcore restrictions include most notably price-fixing agreements, market-sharing agreements, quantity-fixing agreements, capacity-fixing agreements and agreements restricting technological progress.

360 Cf. Europäische Kommission (2011).

361 Cf. http://www.fiw-online.de/de/aktuelles/aktuelles/eu-kommission-veroeffentlicht-ergebnisse-der-evaluierung-der-horizontalen-regelungen-gruppenfreistellungserklaerungen-und-leitlinien and http://www.fiw-online.de/de/aktuelles/aktuelles/eu-kommission-konsultiert-zu-horizontal-gruppenfreistellungsverordnungen-und-den-zugehoerigen-leitlinien (each last accessed on 14 January 2022).

362 Cf. Bundesanzeiger (2021a).

363 Cf. also Haucap et al. (2020: 71 f.) and Haucap. (2021: 447).

B 4

364 Cf. Wissenschaftlicher Beirat beim Bundesministerium für Wirtschaft und Energie (2021: 8).

365 Cf. Bratan et al. (2022: 9) and SVR Gesundheit (2021: XXIX).

366 For an overview of the studies, cf. Bratan et al. (2022: 13).

367 Cf. Bratan et al. (2022: 17).

368 Cf. https://www.bdlev.de/news/15/643967/pressemitteilungen/melde-und-dateninfrastrukturen-der-gesundheits%C3%A4mter-verbessern-und-vereinheitlichen!.html (last accessed on 14 January 2022).

369 Vgl. acatech, Körber-Stiftung, Universität Stuttgart (2021: 23).

370 Cf. SVR Gesundheit (2021: 18 f.).

371 Cf. Deutscher Bundestag (2003).

372 Cf. Bratan et al. (2022: 24) and SVR Gesundheit (2021: 31).

373 Cf. Deutscher Bundestag (2003).

374 In addition, the National Association of Statutory Health Insurance Physicians (Kassenärztliche Bundesvereinigung) was mandated to not only define the contents of the ePR but also to ensure its interoperability, thus enabling a smooth and efficient exchange of digital information between the stakeholders in the healthcare system. Cf. Deutscher Bundestag (2019b).

375 Also, under the Act, statutory health insurance (SHI)-accredited healthcare providers were obliged to equip themselves with the necessary components and services to enable access to the ePR by 30 June 2021. Cf. Deutscher Bundestag (2019a). For more information on SHI-accredited care cf. https://www.aok-bv.de/hintergrund/dossier/aerztliche_versorgung (last accessed on 14 January 2022).

376 The concrete implementation of the legal execution, including the requirements for the examination of the reimbursability of DiGAs, is regulated by the Digital Health Applications Ordinance issued by the Federal Ministry of Health in April 2020. Cf. Bundesministerium für Gesundheit (2020).

377 To be able to bill the services via the statutory health insurance funds, secure information and communication technologies must be used. Cf. Deutscher Bundestag (2019a).

378 Cf. Deutscher Bundestag (2020).

379 Other decentralized components include smart cards such as the electronic health card and the electronic health professional card.

380 The TI application Kommunikation im Medizinwesen (KIM) enables secure electronic data exchange between registered, authenticated users of the TI. Using KIM, messages and documents can be exchanged quickly, reliably and securely by e-mail. Data relevant to treatment, therapy and billing, such as doctors' letters, diagnoses and invoices, are sent via the TI. Another example of central hardware and software components are specialized services such as the central e-prescription service. Cf. https://fachportal.gematik.de/anwendungen/kommunikation-im-medizinwesen/#c2826 (last accessed on 14 January 2022).

381 The available applications of the TI also include the electronic certificate of incapacity to work, the electronic medication plan, emergency data management, the qualified electronic signature, the insurance master data management and the support of other electronic healthcare applications, the secure communication service Kommunikation im Medizinwesen and the TI Messenger.

382 The full name when it was founded was gematik – Gesellschaft für Telematikanwendungen der Gesundheitskarte mbH. In 2019, it was renamed gematik GmbH in the course of the reform. The appointed shareholders of gematik are the central associations of statutory health insurance funds (as of 1 July 2008, the National Federal Association of Health Insurance Funds, GKV Spitzenverband) with 50 percent of shares, the National Association of Statutory Health Insurance Physicians (15 percent), the German Hospital Federation (Deutsche Krankenhausgesellschaft, 12 percent), the Federal Union of German Associations of Pharmacists (Deutscher Apothekerverband, 8 percent), and the German Medical Association (Bundesärztekammer), the German Dental Association (Bundeszahnärztekammer) and the National Association of Statutory Health Insurance Dentists (Kassenzahnärztliche Bundesvereinigung) with 5 percent of shares each. Cf. https://www.gkv-90prozent.de/ausgabe/05/kurzmeldungen/05_serie_gematik/05_serie_gematik.html (last accessed on 14 January 2022).

383 Among other things, all medical service providers were to be connected to the TI by 31 August 2018. The first TI application planned was the introduction of insurance master data management. Cf. here and below SVR Gesundheit (2021: 31 f.).

384 Cf. https://www.gematik.de/ueber-uns/gesetzliche-grundlagen (last accessed on 14 January 2022).

385 Cf. gematik (2020a: 10).

386 Cf. gematik (2020a: 12).

387 gematik is supported in this by an interdisciplinary committee of experts. Cf. gematik (2020b) and https://www.bundesgesundheitsministerium.de/service/gesetze-und-verordnungen/guv-19-lp/gigv.html (last accessed on 14 January 2022).

388 Cf. Bratan et al. (2022: 45).

389 Cf. OECD (2019) and Campanella et al. (2016).

390 Cf. SVR Gesundheit (2021: 78).

391 Cf. Highfill (2019). In addition, the results of a meta-study from the UK suggest that the initial cost of an ePR pays for itself in the long term through improved billing accuracy. Cf. Priestman et al. (2018).

392 Cf. Namulanda et al. (2018), Abul-Husn and Kenny (2019), Coorevits et al. (2013) and Cowie et al. (2017).

393 The Appointment Service and Care Act passed in 2019 sets binding deadlines for the introduction of the ePR. Detailed regulations for the introduction of the ePR, such as access management under data protection law and use for research, are legally regulated and specified in the Patient Data Protection Act, which came into force in 2020. Cf. Deutscher Bundestag (2019b).

394 Information on pre-existing conditions, prescribed medication and allergies can be stored in the emergency record. In medical emergencies, healthcare providers can read these. https://gesund.bund.de/notfalldatensatz-nfd (last accessed on 14 January 2022).

395 Furthermore, an integrated TI Messenger is planned, enabling patients to contact doctors directly. Cf. https://fachportal.gematik.de/anwendungen/ti-messenger (last accessed on 14 January 2022).

396 Cf. https://www.zeit.de/digital/2021-12/elektronische-patientenakte-digitalisierung-gesundheitswesen-faq (last accessed on 14 January 2022).

397 An opt-in procedure is one in which the data subject must actively and explicitly consent to the access and processing of their data.

398 Cf. SVR Gesundheit (2021: 86).

399 An opt-out procedure is one in which the data subject must actively object to the access and processing of their data.

400 Cf. Bratan et al. (2022: 48).

401 Cf. 118. Deutscher Ärztetag (2015).

402 Cf. Mangiapane et al. (2020), Obermann et al. (2020) and Richter and Silberzahn (2021).

403 Cf., among others, Ekeland et al. (2010), Snoswell et al. (2021), van den Berg et al. (2012) and Timpel et al. (2020).

404 Cf. Battineni et al. (2021).

405 Cf., among others, Marcin et al. (2016) and Zeltzer et al. (2021).

406 Cf. Schuster et al. (2019).

407 Cf. Merkel and Hess (2020).

408 Cf. here and below Bratan et al. (2022: 38 f.) and SVR Gesundheit (2021: 85 f.).

409 Cf. https://www.elga.gv.at/elga-die-elektronische-gesundheitsakte/zahlen-daten-fakten (last accessed on 14 January 2022).

410 Cf. Séroussi and Bouaud (2020).

411 Cf. https://www.kbv.de/html/videosprechstunde.php (last accessed on 14 January 2022).

412 Cf. KVNO (2020), https://www.kbv.de/html/videosprechstunde.php and https://www.foerderdatenbank.de/FDB/Content/DE/Foerderprogramm/Land/Niedersachsen/digitalisierung-im-gesundheitswesen.html (each last accessed on 14 January 2022).

413 Cf. Richter and Silberzahn (2021). Before the introduction of DiGAs within the framework of the Digital Care Act, the remunerated use was limited to use provided within the framework of selective contracts, primary prevention, provision of medical aids and as a new examination and treatment method. Cf. SVR Gesundheit (2021: 177 f.).

414 Cf. https://www.bfarm.de/DE/Medizinprodukte/Aufgaben/DiGA/_node.html (last accessed on 14 January 2022).

415 For permanent inclusion, further evidence of the positive medical benefit of the DiGA must be submitted by the end of the trial period of one year. Permanent inclusion is also possible for provisionally listed applications after the trial period and the submission of the necessary studies. Cf. BfArM (2021).

416 Cf. https://diga.bfarm.de/de/verzeichnis (last accessed on 14 January 2022).

417 Cf. BKK Dachverband e. V. (2022). Previously, it was estimated that around 53,000 DiGA prescriptions were issued or applied for in the first year of their availability. Cf. Urbanek (2021).

418 Cf. SVR Gesundheit (2021: 167).

419 Cf. Dahlhausen et al. (2021).

420 Cf. Wangler and Jansky (2021).

421 Cf. Schiedsstelle (2021).

422 Cf. https://fbeta.de/die-unangepassten-digas-bringen-frischen-wind-in-das-etablierte-vergue tungssystem (last accessed on 14 January 2022).

423 Public health is defined as the science and practice of preventing disease, prolonging life and promoting health through organized efforts of society. It includes, among others, the fields of prevention, target group-specific health research and health services research. Cf. Acheson (1988), https://www.euro.who.int/en/health-topics/Health-systems/public-health-services/public-health-services and https://www.gesundheitsforschung-bmbf.de/de/public-health-9442.php (each last accessed on 14 January 2022).

424 Cf. EFI (2021: 80), SVR Gesundheit (2021: 227 f.) and https://www.aerzteblatt.de/nachrichten/130000/Gutachten-zur-Weiterentwicklung-medizinischer-Register-vorgestellt (last accessed on 14 January 2022).

425 These include, among others, supply and billing data as well as data from official statistics. For a detailed overview cf. SVR Gesundheit (2021: chapter 5.3). Secondary use is defined by the American Medical Informatics Association (AMIA) as 'non-direct care use of personal health information including but not limited to analysis, research, quality/safety measurement, public health, payment, provider certification or accreditation, and marketing and other business including strictly commercial activities'. Cf. Safran et al. (2007).

426 Cf. Bronsert et al. (2013) and SVR Gesundheit (2021: 228).

427 Cf. Myers und Stevens (2016), Cowie et al. (2017) and Casey et al. (2016).

428 Cf. Thiel et al. (2020: 19 f.).

429 Cf. https://www.gesundheitsforschung-bmbf.de/de/quo-vadis-medizin-wie-moderne-it-technik-hilft-die-gesundheit-der-menschen-zu-verbessern-9599.php and https://www.digitale-technologien.de/DT/Redaktion/DE/Standardartikel/KuenstlicheIntelligenzProjekte/KuenstlicheIntelligenz_ErsterFoerderaufruf/ki-projekt_empaia.html (each last accessed on 14 January 2022).

430 Cf. https://www.gesundheitsforschung-bmbf.de/de/digitalisierung-und-kunstliche-intelligenz-9461.php (last accessed on 14 January 2022).

431 Cf. RKI(2021).

432 Cf. https://digital-strategy.ec.europa.eu/en/policies/1-million-genomes and https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/de/deutschland-tritt-genomprojekt-der-eu-bei.html (each last accessed on 14 January 2022).

433 Cf. CBInsights (2021) and https://www.holoniq.com/healthtech-unicorns (last accessed on 14 January 2022).

434 Ottobock, a family-owned company that has been active in orthopaedic technology for over 100 years, describes itself as a global technology leader in the field of wearable human bionics that augment or replace parts of the human body. Cf. https://www.ottobock.com/de/unternehmen/ueber-ottobock (last accessed on 14 January 2022).

435 The Berlin-based start-up ATAI Life Sciences is developing psychedelic substances based on mushrooms for use against depression and other mental illnesses.

436 Cf. Hosseini et al. (2021).

437 Cf. https://nanoporetech.com (last accessed on 14 January 2022).

438 Cf. https://web.noom.com/about-us (last accessed on 14 January 2022).

439 Cf. SVR Gesundheit (2021: 23 f.).

440 The acronym FAIR stands for Findable, Accessible, Interoperable, Reusable. Cf. Wilkinson et al. (2016).

441 Cf. https://www.medizininformatik-initiative.de/de/ueber-die-initiative and https://www.gesundheitsforschung-bmbf.de/de/medizininformatik-aufbau-und-vernetzungsphase-7639.php (each last accessed on 14 January 2022).

442 Cf. https://www.medizininformatik-initiative.de/de/snomed-ct-haeufig-gestellte-fragen (last accessed on 14 January 2022).

443 Cf. https://www.nfdi4health.de/ueber-uns/hauptziele.html and https://gepris.dfg.de/gepris/projekt/441914366 (each last accessed on 14 January 2022).

444 For data processing, the combination of health and social data with register data and the data protection aspects, a separate law, the so-called Act on the Secondary Use of Health and Social Data, was passed in 2019. Cf. http://findata.fi/en/what-is-findata (last accessed on 14 January 2022).

445 Cf. https://www.forschungsdatenzentrum-gesundheit.de/das-fdz (last accessed on 14 January 2022).

446 Cf. gematik (2020a) and https://www.nfdi4health.de/ueber-uns/hauptziele.html (last accessed on 14 January 2022).

447 Cf. SPD et al. (2021: 83).

448 Vgl. acatech, Körber-Stiftung, Universität Stuttgart (2021: 41 and 45).

449 Cf. Thiel et al. (2018: 90 and 100 f.).

450 Cf. Weichert (2019).

451 Cf. Dahlhausen et al (2021), https://background.tagesspiegel.de/gesundheit/warum-aerzte-digas-nicht-verschreiben and https://www.aerzteblatt.de/nachrichten/117236/Apps-auf-Rezept-Noch-viele-Unsicherheiten-bei-Aerzten (each last accessed on 14 January 2022).

452 Cf. Richter and Silberzahn (2021).

453 Cf. Richter and Silberzahn (2021).

C 1

454 Cf. Kerst et al. (2022).

455 The sharp decline in the number of students qualifying to study in 2020 is not only due to demographic factors, but predominantly due to the special effect of Lower Saxony's return to the nine-year secondary school model. Cf. Kerst et al. (2022).

456 Delayed final examinations during the COVID-19 pandemic may have contributed to the decline, among other things. Cf. Kerst et al. (2022).

C 2

457 Cf. Kladroba et al. (2022).

458 In Schasse (2021), the value for the USA in 2018 was given as 2.83 percent. The discrepancy of 0.12 percentage points results from more recent calculations in Kladroba et al. (2022).

459 In contrast to the last survey, the current study uses 2010 as the index year.

460 In the study by Schasse (2021), R&D expenditure was given as a percentage of turnover from own products. In the current study, they are given as a percentage of total turnover.

C 3

461 Cf. here and below Rammer und Hünermund (2013).

462 Cf. here and below also Rammer et al. (2022).

463 Cf. Blind (2002).

464 Cf. ISO (2012) and https://www.iso.org/members.html (accessed on 23 December 2021).

C 4

465 This section and the following figures are based on Kladroba et al. (2022) and Bersch et al. (2022).

466 Invest Europe is the European association of private equity and venture capital investors and operates the European Data Cooperative (EDC), a platform for collecting private equity and venture capital data. Based on the information in the EDC database as well as data from Eurostat and the International Monetary Fund, Invest Europe provides updated data on venture capital investments at regular intervals. This is based on information from the national venture capital associations, which obtain their information through member surveys. The harmonized collection and processing of data ensures good international comparability.

467 This is the case if investing market participants are not registered as members of Invest Europe or if it is a non-European investor.

468 The Zephyr M&A database contains information on mergers and acquisitions (M&A), separated into private equity, venture capital and business angel investments. The information includes the investment sum, the company in which the investment was made (portfolio company) and the investor. As the Zephyr M&A database primarily contains larger investments, the information from this database is supplemented by that from the Majunke transaction database. This database is provided by Majunke Consulting and covers venture capital investments in Germany, Austria and the German-speaking part of Switzerland. It likewise contains information on the investment sum, the portfolio company and the investor, and includes small investments. Since both databases also contain a number of other investments in companies in addition to venture capital investments, each transaction is checked to determine whether it is actually a venture capital investment with a sufficiently high probability. For this, information from the Mannheim Enterprise Panel (Mannheimer Unternehmenspanel, MUP) on the (natural and legal) persons involved in a company is used.

469 Atypical investors are all those market participants who make direct venture capital investments but whose core business is different. These include, for example, asset managers, umbrella funds, banks and insurers as well as established companies.

C 5

470 However, the comparability of individual country data is not without reservation. Cf. here in detail Müller et al. (2014).

471 The evaluations of the business registers in the individual Member States form the basis for the official database. The values for Germany come from the business demography statistics of the Federal Statistical Office (Statistisches Bundesamt), which is an evaluation of the business register. Cf. here in detail Müller et al. (2013).

472 Cf. here and below Bersch et al. (2022).

473 The MUP comprises the total stock of economically active enterprises in Germany, as far as they are recorded by Creditreform. It covers all company information available at Creditreform and includes companies that no longer exist. In total, the MUP contains information on more than eight million companies that are economically active in Germany or were economically active in the past. The ZEW puts these data into a panel structure and carries out various quality controls (e. g. deletion of multiple entries, imputation of missing values to the business sector, identification of closing characteristics). For the calculation of the total number of start-ups at the current margin, extrapolations are made to take into account the time lag between a start-up event and its recording by Creditreform. Cf. Bersch et al. (2022) and https://www.zew.de/forschung/mannheimer-unternehmenspanel last accessed on 14 January 2022).

474 An original start-up is when a business activity that was not previously carried out is taken up and at least one person earns their main income from it. Only original start-ups are considered for the analysis of start-up dynamics. Re-establishments of enterprises, the establishment of holding companies and the new establishment of commercial enterprises due to a move or commercial enterprise in secondary activity are not counted as start-ups. Spin-offs from enterprises are counted as original start-ups, provided that the enterprise from which the spin-off takes place does not hold more than 50 percent of the spin-off enterprise. A company closure occurs when a company no longer carries out any economic activity and no longer offers any products on the market. Cf. Bersch et al. (2022).

475 The MUP has a much narrower definition of economically active enterprises, so that small-scale entrepreneurial activities are not covered by the MUP. In addition, market entries and exits are defined differently in the MUP. In the MUP, a start-up

is deemed to have taken place if a previously not executed business activity is taken up, the extent of which corresponds at least to the main gainful activity of a person. A closure occurs when a company does not carry out any economic transactions in a year and does not offer any goods for sale in the market. Cf. Müller et al. (2013) on the various data sources.

476 Cf. here and below Bersch et al. (2022).

477 Cf. here and below Bersch et al. (2022).

478 Cf. here and below Bersch et al. (2022).

C 6

479 Cf. Neuhäusler and Rothengatter (2022).

C 7

480 Cf. Stephen and Stahlschmidt (2022).

C 8

481 This section and the following figures are based on Schiersch et al. (2022).

482 For a methodological explanation of the RCA indicator, cf. Schiersch and Gehrke (2014: 74 f.).

D 4

483 Cf. Gehrke et al. (2013).

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